NEEDLE IN A HAYSTACK: HUNTING MOBILE THEATER MISSILES ON THE BATTLEFIELD

A MONOGRAPH
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ABSTRACT

NEEDLE IN A HAYSTACK: HUNTING THEATER MISSILES ON THE BATTLEFIELD by MAJ Scott M. Reynolds, USA, 80 pages.

The proliferation of weapons of mass destruction and their delivery means - tactical ballistic and cruise missiles - have caused anguish in the West. Few nations are equipped to defend against theater missiles. Theater missiles encompass the broad category of missiles incorporating tactical ballistic and cruise missiles. Indeed, the U.S. and their coalition partners discovered the difficulties in Operation DESERT STORM.

One of the four pillars of theater missile defense is attack operations. It is an offensive strategy aimed at attacking the missile launchers, missile, guidance mechanism, command and control, and resupply system. This monograph investigates attack operations from an intelligence perspective. Its intent is to delve into the relationship intelligence has to the operations and targeting staffs. The author begins by exploring the history of attack operation to determine procedures and lessons that may still have applicability today. Next, IPB is introduced as a systematic negative search methodology. Targeting is covered from a command and control, attack, and measures of effectiveness perspective. Finally, the author grapples with the issue of sensor allocation.

What is needed is a good beginning knowledge of the enemy capabilities, doctrine, training, operations, leadership, and organization. Building a database during conflict is problematic. Second, the joint headquarters must have adequate and practiced theater missile defense doctrine, TTPs, communications, intelligence, and command and control relationships. The ability to put all of the pieces together synergistically is the key to success in attack operations.

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I. Introduction. Western statesmen agree that worldwide proliferation of ballistic and cruise missiles represents a serious and increasing threat. Ballistic missiles have already emerged as a preferred weapon of strategic intimidation for third-world regimes. Indeed, former U.S. Secretary of Defense Dick Cheney stated following Operation DESERT STORM:

> The Persian Gulf War was not the first in which ballistic missiles were used, and there is no reason to think that it will be the last. Indeed, ballistic missiles were the only weapon systems with which Saddam Hussein was able to take significant offensive action against U.S. forces and allies, and the only one to offer him an opportunity (via the attacks on Israel) to achieve a strategic objective. We must expect that even more countries will acquire ballistic missiles and will be prepared to use them in the future.[1]

Thirty-six countries now possess ballistic missiles of some type, and 14 of these produce them. Five other countries are developing ballistic missiles or have the capability to develop them. Cruise missiles are fast emerging as another choice weapon of strategic intimidation. Some 19 countries produce cruise missiles, and a further 54 count them as part of their arsenals.[2] Appendix B and C provide a list of missile capabilities and holdings by countries.

The chance that U.S. interests are threatened by a hostile state with missile attack grows with the proliferation of increasingly long-range ballistic and cruise missiles. This is a serious threat, but one that is compounded by the parallel proliferation of Weapons of Mass Destruction (WMD). Many of the same countries that are developing ballistic and cruise missiles are also in various stages of developing WMD. This confirms the supposition that adversaries possessing theater missiles (TMs) armed with WMD

warheads pose the greatest danger to Western interests and those of their allies in the next century.[3]

To halt the spread of ballistic and cruise missile technology, the United States has entered into the Missile Technology Control Regime (MCTR) with Russia, Ukraine, and South Africa. The U.S. has actively pursued the inclusion of other nations to broaden the membership in the MCTR. China, Hungary, Argentina, and Brazil have joined the MCTR or agreed to abide by its provisions.[4] Despite these measures, proliferation continues.[5]

Over the next decade, these missiles will come to pose an increasing strategic and operational threat to the interests of the western powers and their allies. This is particularly so because many of the nations that have acquired ballistic and cruise missiles are led by tyrannical, or by weak and unstable governments. As Saddam Hussein's invasion of Kuwait in 1990 demonstrated all too clearly, the doctrines of deterrence that underpinned Western security during the Cold War may no longer work.[6]

Operational commanders must deal with the threat to their deployed forces. Few adversaries have assets with the range to strike the United States. However, in-theater forces are at risk. Tactical ballistic and cruise missiles provide an attractive option to offset the conventional might of the Western powers, particularly the U.S. They afford an asymmetrical means to strike at critical targets and the will of allied forces. DESERT STORM saw the use of these weapons against U.S. and coalition forces by a Third World country (Iraq). Our efforts to find and destroy these very mobile high priority targets on the battlefield were something less than successful.[7]

Theater missile defense rests on four pillars that must work in concert: attack operations, active defenses, passive defenses, and command, control, communications, and intelligence (C4I). Attack operations are those that seek out and destroy the enemy's ability to launch tactical ballistic and cruise missiles. It is an offensive strategy. Active and passive defense includes those defensive measures that defeat the missiles after launch. The Patriot air defense system is an active defense complex. It seeks to destroy the missile after it is launched, but before it strikes the target. Passive defense tries to weather a missile strike. Examples of this are hardened built to survive an attack, camouflage and concealment designed to hide lucrative targets from the enemy's prying eyes, deceptive measures set up to entice the enemy to strike less important assets or decoys, and dispersion of assets to limit damage from an impact. C4I coordinates the allocation of resources and information that allows the other three pillars to work in consonance with one another.[8]

This monograph strictly pertains to attack operations, also referred to as counterforce operations. Specifically, it will identify the methodology for optimizing intelligence techniques, sensor mixes, and linkages with operations elements. The intelligence collection and analysis required to conduct counterforce operations are substantially different from those required of situation development, and indications and warning. It is a refined form of target development, with a mixture of predictive intelligence. The target is not a unit, but an individual transporter - erector- launcher (TEL) vehicle. The mobility of which make them difficult to locate and track.

What the intelligence community has yet to come to grips with is a methodology for searching for and tracking high priority targets. Specifically, intelligence professionals need to acquire the skills to identify the specific components of the problem set, synergistically synchronize sensors to optimize the advantages of each for the problem at hand, and deal with the massive amounts of data available to them. Albeit these problems seem as diversified as one can get in the intelligence business, they cut to the core of the operational attack problem.

The criteria for evaluating the efficacy of the methodology for locating and tracking TMs is accuracy of predicting and locating TM TELs, appropriate utilization of the available sensor suite, ability to fuse multi-source data to locate, discriminate and track TBMs, and ability to cue attack asset in sufficient time to conduct counterforce operation.

Targeteers must grasp the nature of the TM threat, its strengths and weaknesses, as well as the ability of friendly attack assets to take advantage of the weaknesses, while minimizing their own vulnerabilities. The intelligence staff is integral to a successful solution throughout this process. At issue are the questions, what makes the TM threat so viable and what can be done about it.

II. Problem Statement. Besides the odious WMD issue, concerns arising from the nature of the TM threat require resolution. The most obvious involve the increased precision afforded by the U.S. Global Positioning Satellite (GPS) and the Russian Global Navigation Satellite System (GLOSNASS) assisted guidance mechanisms, the limited defensive capabilities against TMs, and the difficulties in targeting single launch elements.

A. Precision Munitions vs. WMD Capabilities. Ballistic and cruise missiles have been around since Germany launched the V-1 and V-2 destruction weapons of the Second World War. Their accuracy, however, had made them little more than terror weapons. Scud B missile variants, the most prolific ballistic missiles available today, have a circular error probable (CEP) of about 450 meters.[9] Since CEP is the probability that 50 percent of the rounds fired will land within a circle with a radius denoted by the value, Scud missiles are extremely inaccurate weapons. That is, until one considers that Scuds were designed to carry nuclear and chemical weapons, which do not need the requisite accuracy to be effective. Scuds are intended to act as terror weapons against civilian population centers and other rear area targets where they can achieve maximum impact on morale, much as the German "V" weapons did in WWII.

That a rogue Third World nation may play the nuclear card is the most fearful proposition imaginable for Western powers. Slightly less dramatic is the potential for biological and chemical weapon use. As proliferation of WMD increases, the probability of their use also grows.

Heedless of the warhead composition, the danger from TMs due to improved guidance increases daily. The U.S. GPS and its Russian counterpart GLOSNASS provide resolutions to within 16 and 17 meters of the receiver's three-dimensional location in space, respectively. GPS was sold to the U.S. Congress as a dual-use technology to aid military and commercial navigation of aircraft, ships, and vehicles. Its military value was demonstrated to the world during Operation DESERT STORM.[10] Since then, countries such as China, have developed course correction mechanism for their TMs using GPS

and/or GLOSNASS. Greatly improved accuracy due to these course correction features could reduce the Scud's CEP to tens of meters. GPS assisted guidance on TMs may prove accurate enough to relieve many second generation missiles of their "terror weapon" moniker, and place them in the precision weapon category.[11]

From a tactical prospective, the most likely targets for precision TMs are critical command and control (C2) nodes and logistical sites in the enemy rear areas. This improved accuracy also negates, to a certain extent, the need to carry WMD payloads. They can destroy the target with conventional munitions, increasing their legitimacy by avoiding the use of morally reprehensible weapons.[12]

Third-world nation-states do not have the economic means to confront western powers militarily. TMs with precision guidance might provide that opportunity. It is the equivalent of the poor man's air force. Asymmetrical strikes on a partially deployed western power, such as the United States, could prove disastrous not only for the force, but also for the mission as well. The destruction of valuable equipment and personnel, through surgical strikes, would set an early entry deployment back months. Significant losses surely would erode support for the operation in the United States. Battlefield losses plus moral degradation in theater and at home might spell doom for the operation.[13]

B. TM Defense. Defending against TMs is difficult, at best. Few countries have adequate active defenses. A greater number have no defenses at all. The U.S. was foresighted enough to address the problem with the Patriot PAC-2 air defense missile system in the late 1980s. Since the Gulf War, the U.S. Department of Defense has spent considerable money and time trying to shore up the deficiencies found in Patriot during

Operation DESERT STORM.[14] Cruise missiles, on the other hand, may present a more difficult target. They display a much smaller signature for a shorter period of time, due to low altitude, nap of the earth approaches. Stealth features are also generally built in to complement their already small size.[15]

For all of the improvements made to active defenses they are just that; defenses. Initiative remains with the attacker, and not the defender. Furthermore, studies by Kneel T. Marshall, Professor of Operations Research at the U.S. Naval Postgraduate School indicate that without adequate counterforce, TMs could easily overwhelm active defenses.[16] The joint community needs to shunt more effort into counterforce or attack options to reduce the enemy capability before launch. The joint community requires training, methodologies, and doctrine that optimize the services and support agencies in an integrated, synergistic effort to stamp out launch and support facilities before employment against U.S. forces and their partners.

TM defense must rely on four elements: counterforce (attack), active and passive defenses, and C4I. The robustness of each pillar in the triad represents increased freedom of action for the commander. Denying the enemy effective use of TMs amounts to force multiplication for the friendly side.

C. TM Model: What to attack is another important question. Strategically and operationally, targets may include the national apparatus commanding and controlling TMs, missile and WMD component manufacturing and assembly, foreign weapons and critical materials agreements and transfers, and a myriad other pieces that make up or support the TM system. Tactically, TM systems normally have several major components.

Among these are the missile, the launcher, a command and control apparatus, a guidance mechanism, and a support structure (resupply vehicle, missile reloads, fuel, etc.). A simplified model for the employment of TM systems is provided below in figure 1.

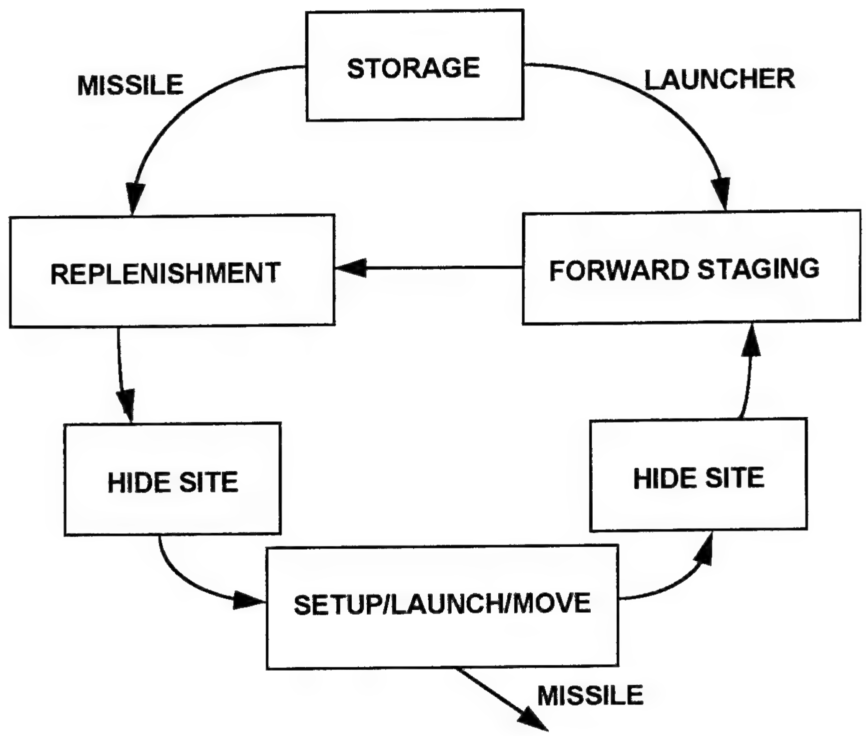

Figure 1. Theater Missile Launch Sequence[17]

Deciding what to attack, and when and where to debilitate the targets to achieve the desired effect is part of the equation. The first order of business is usually to attempt to locate and destroy the missile launchers. This is the most immediate and pressing need. Without the launch facility, the missiles cannot fire. Obviously, it would be better to strike TM launchers, command and control, and infrastructure before the enemy deploys and hurls missiles at friendly forces.[18] It is unlikely that the executive branch of the U.S. government would sanction a first strike for political reasons. The challenge is to find

deployed launch assets at or shortly after the initiation of hostilities. This is a huge challenge, as witnessed during DESERT STORM.

Most countries probably learned key lessons about deploying mobile launchers from the Iraqis during the Gulf War. First, keep the launchers separated and operating individually. Single launcher deployment retains maximum survivability. Reloads and other logistical support also require dispersion. Second, cover and concealment are critical. Using hide sites and camouflage increases the TELs survivability manifold. The launcher should only come out at night and for a limited time. Third, dummy vehicles confuse the enemy and draw combat power away to attack these tactical decoys. Since a western power has only so much airpower and long range fires, enticing them with deception efforts whittles away at that valuable resource on worthless targets. It also confounds attempts at definitive battle damage assessment (BDA).[19]

D. Locating Mobile TM Launchers: In terms of the dispersed battlefield, ballistic and cruise missiles are part of the future of warfare, not a dead end. TMs deepen the battlefield even further. With ranges averaging around 300 kilometers for the current stockpile of 1950's era missiles, the ranges in the next decade could average thousands of miles. The distances allowed by these strategic and operational weapons are significant. In effect, a belligerent can place long range ballistic and cruise missiles anywhere in his territory and fire them at an adversary. The dispersion allowed by increased weapon system ranges grants maximum security for the fires complex.[20]

The security afforded by the ability to use a greater area from which to fire expands the search area exponentially. A soldier with a rifle can place effective fire to

about 300 meters covering an area of about 282.74 square kilometers. A howitzer with a range of about 30 kilometers can effectively fire in an area of about 449.5 square kilometers. A TBM with a range of 300 kilometers, average Scud range, can hit targets in an area of up to 43,987.5 square kilometers.[21] The extensions in range presume increasingly greater areas from which the weapons can operate and still reach their targets. This expansion in operating domain also increases the territory to be searched.[22] Because of the ever-increasing range of systems it becomes more and more important that wide area search systems are in the inventory.

The design of U.S. remote intelligence assets and doctrine focuses on monitoring stationary pinpoint targets, or detecting and locating large formations. The dichotomy between these two functions is clear. Sensor design has followed a peacetime indication and warning, and scientific and technology path. They were never designed to conduct wide area search and pick individual targets out of vast spaces. The soda straw, or small field of view (FOV) approach is not amenable to wide area search for individual TM launchers, but there are ways to integrate these capabilities into a more effective search methodology.

Certain implications accrue from the increased range of the weapon systems. Most missiles and artillery systems have a minimum range within which the weapon cannot strike the target. For Scuds and other tactical ballistic missiles it is the physics by which they are designed. They are launched in a direction, and when the plume extinguishes it falls freely in a ballistic glide path back to earth. Since cruise missiles need a certain amount of space to arm themselves, it provides sensors and attack assets security from the

effects of the missile when operating within that minimum range. It also helps narrow the possible search area, that is if the analyst can define the target set aimed for by the enemy. Furthermore, through maneuver the friendly force commander can force the enemy to abandon his target set. This is accomplished by making the foe move beyond of his optimal firing range.

E. Data Management: The volume of information entering the data networks of U.S. forces is staggering. With the growth of communication capacities, the amount of information has skyrocketed. Figure 2 illustrates the dramatic rise in communications capacity.

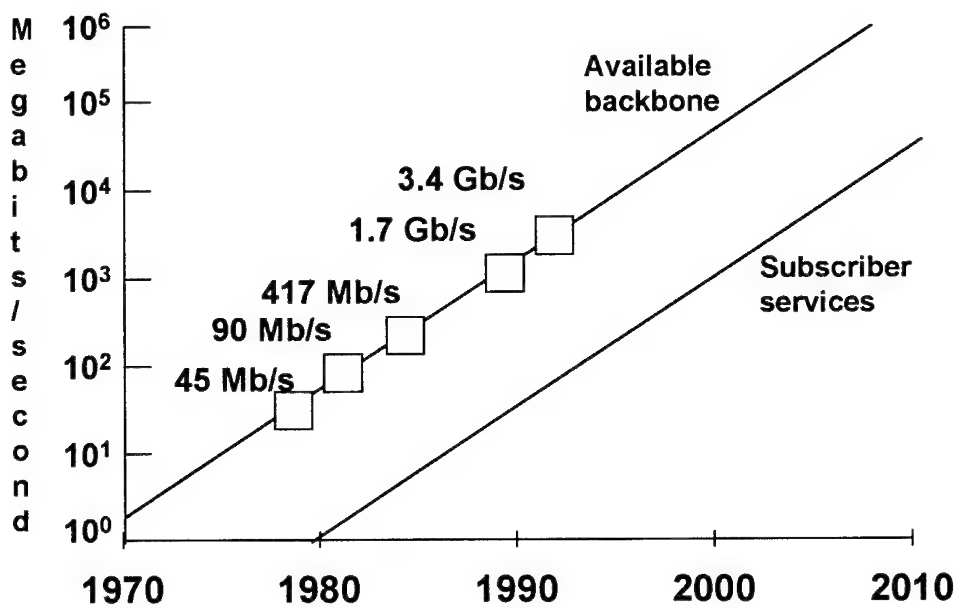

Figure 2. Trends in Communications Capacity[23]

Managing the torrent of data flowing into a headquarters, making sense out of it, and culling it down to a usable form for making decisions is critical. The difficulties in doing this increase every year. More "stuff" becomes available over the Defense Communications System (DCS), Global Broadcast System (GBS), internal organizational

networks and links, or through the coalition or allied sources. Management of intelligence data is especially critical, due to its time sensitivity.

Alacrity with which the command and staff deals with information does not necessarily determine success. There is just too much of it to digest. In order to deal with the ever burgeoning throughput of information, one has to either decrease volume or increase proficiency of assimilation. Weeding out the information of limited utility in favor of high yield data is one way to sift through the torrent. Another is to fight fire with fire, by using high speed processors to increase the available pool of information through automated databases and manipulation (Figure 3). The U.S. armed services have opted for the latter methodology. However, both are useful and not mutually exclusive.

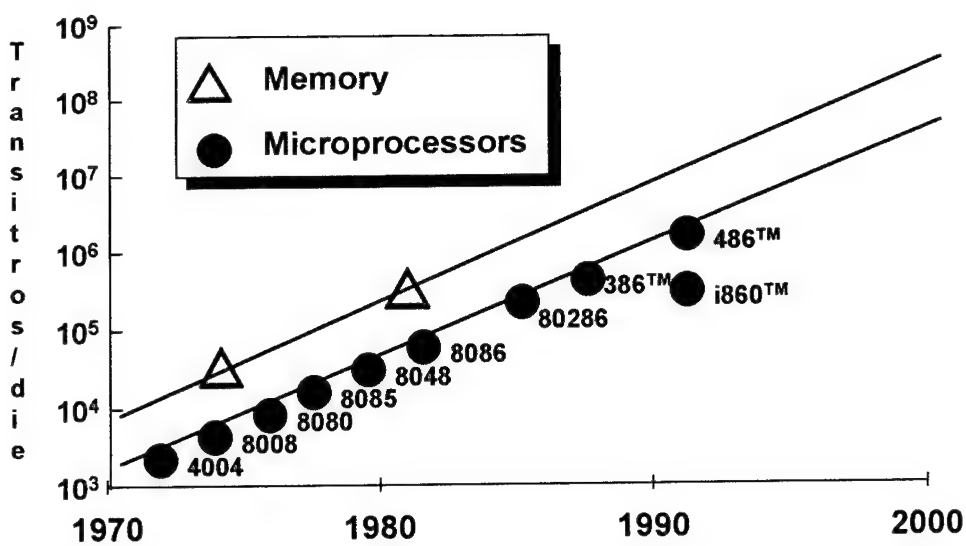

Figure 3. Transistors per Chip[24]

III. History of U.S. Tactical Missile Counterforce. Understanding the historical context in which U.S. efforts against mobile high priority targets, such as TMs, facilitates conceptualizing the difficulties inherent in present counterforce operations. Three

examples suffice to highlight prior counterforce efforts. The Allied attempts to squelch the German V-1 and V-2 threats during WWII provided the first opportunity to explore TM counterforce methods. With the rise of intercontinental ballistic missile forces in the Cold War, arms control verification became critical to national security. The latest Strategic Arms Reduction Treaty (START) verification methodologies present an occasion to view planning during peacetime for potential counterforce operations. Finally, Operation DESERT STORM offers the latest lessons learned with the infamous Iraqi Scud hunt.

Ballistic and cruise missiles were parallel developments of the aviation and space age. The German V1 and V2 missile systems were crude and inaccurate by today's standards, but ushered in the age of guided missile weaponry. They were the first viable CM and TBM systems, respectively.

A. The German Vengeance Weapons: Cruise missile development began during WWI with the flying bomb, although the concept predated that war. It took until WWII and the fielding of the V-1 to realize the vision. The V-1 was a pilotless bomber powered by a pulse jet engine that allowed it to travel between 340 and 400 miles per hour for a distance of approximately 150 miles. Its normal operating altitude was 2,000 to 3,000 feet above ground level. The V-1's guidance system consisted of a gyro autopilot to keep the weapon on a preset magnetic azimuth.[25]

The first successful impact of the V-1 against London occurred on June 13, 1944. By the end of the war the Germans had launched as many as 19,500 V-1s. The casualties were roughly 11,000 killed and 28,000 injured.[26] The relatively small loss of life was due

in large part to the inaccuracy of the missiles, poor targeting by the Germans, predictability of the missile flight path, and good defensive measures on the part of the allies. Combined V-1 and V-2 attacks, however, caused widespread panic and the evacuation of up to 1,500,000 civilians from London. Tremendous political pressure to end the missile attacks forced General Eisenhower to raise the priority of the V-1 and V-2 countermeasures program over all other requirements except for the highest ground war needs.[27]

Initially, the V-1 launch sites were relatively easy to identify and target. The V-1 required a large ramp structure (138 to 170 feet long) to launch the missiles. These "ski sites", as they were called by the Allies, were difficult to camouflage and conceal. From December 1943 to 10 June 1944 Allied bombing put 82 of the 96 operational sites out of commission. Recognizing the vulnerability of the fixed sites to Allied intelligence and targeting, the Germans constructed smaller, easily concealed and camouflaged sites. These modified ski sites were also targeted, and 24 of 88 were destroyed by 15 July 1944.[28] Targeting the original and modified ski sites reduced the launch of the V-1s, but cost the allies dearly. Allied counterforce efforts on the continent cost at least 351 bomber aircraft and 2,183 crew members. The real degradation from counterforce, however, came when the allies bombed the storage and manufacturing facilities.[29]

Regardless, the Axis was not severely deterred by the counterforce actions. Active defenses were the real hero in the fight against the V-1 missiles. Allied forces learned the value of air defense artillery, and not the efficacy of cruise missiles. Due to the limitation of the missiles, it was easier for the Allies to rely primarily on active defense. The success

of these active defenses had adverse effects following WWII. The U.S. and Britain consistently underrated the value of cruise missiles and underfunded development of their own missile systems. Their over-confidence in active defense measures assured that they would not develop rigorous counterforce procedures. The methods and means to conduct successful counterforce were not ingrained.[30]

The V-2 ballistic missile system was much more difficult to defeat, despite its more intricate design. It had mobility, struck silently, and was impossible to defend against once launched. The V-2 was a single-stage, liquid-fueled weapon with an inertial guidance system and a range of about 200 miles.[31] It was trucked around on a mobile launcher to pre-surveyed sites, set up, and fired. The German's fired 3,150 V-2 missiles against targets in United Kingdom and on the continent, killing approximately 2,500 British citizens.[32] They were defeated only by ground force occupation of their launch sites.[33]

With regard to counterforce, the main force protection differential between the V-1 and V-2 missile systems was the V-2's mobility. The V-1 could only use existing ramps, or airplanes for launches. Since airplanes and pilots were scarce by 1944, ski sites became the only practical method of launch.

Since WWII there have been fourteen known conflicts involving TBM and CM launches. Appendix C lists these instances. For the next thirty years the ballistic and cruise missile club remained almost exclusively the purview of the major western powers. In the 1970s many Third-World countries acquired sufficient missile technology to modify foreign missiles or begin development on their own. Today, at least 77 nations have or are developing TMs. To understand the impetus behind the proliferation of TMs the reviewer

must understand the history of TBM and CM development. The principles used in the manufacture and deployment of the V-1/V-2 missiles provided the impetus and technological markers needed by the allies to develop their own systems.

B. START Verification: START verification during the Cold War was primarily a conflict of national technical means. Mobile missile monitoring during war requires these same national technical means. Differences in approaches do occur that hinder our ability to directly apply the treaty verification model to operations during national crisis. First, operations during a crisis place a premium on precision and timeliness of intelligence information. Decision-makers most often want information about the quantity, status, and locations of deployed systems. Targetable data must reach warfighters in time to support strikes on launch and support units, or C2 elements. Second, the long term aspects of treaty verification allow analysts to build a data base that may not be available during war. The Gulf War provides an excellent example of the lack of intelligence data on the types, numbers, organizations, doctrine, and locations of TM systems in Iraq. Building an intelligence database during wartime can provide disastrous results. Third, an arms control treaty generally provides measures for inspections and other forms of corroboration of the terms of the agreement. No such cordial arrangements are possible in conflict and war. By contrast, intelligence efforts at treaty verification focus on anomalies in force status, readiness, and size, and system characteristics, doctrine, and operations. Detecting variations in the size, capability, and status of the missile force is the aim. Long-term sampling provides decision-maker's confidence in the compliance of the other signatories.[34]

C. DESERT STORM: America's most recent test facing a TBM threat came in Operation DESERT STORM. The U.S. was not well prepared to conduct counterforce operations against Iraq for several reasons. First, the Scud missile, and its variants, used by Iraq were renowned for their inaccuracy. It was strictly a terror weapon. Second, U.S. Central Command (USCENTCOM) targeted only the fixed sites for the initial phase of the air campaign. Reduction of these sites was presumed to have eliminated the most pressing threat. Third, although U.S. analysts knew that Iraq had mobile TELs, their numbers were believed to be small and their detection would be relatively effortless.[35] History shows this was a gross error on the part of the planners.

In fact, the Scud missile did not have the accuracy necessary to seriously concern military commanders, except when it threatened to break up the coalition by bringing Israel into the fray.[36] The political ramification of Israel's entry into the war was enough to tie the Commander-in-Chief's (General Schwarzkopf) hands, forcing him to raise the priority of Scud related target to the highest priority.[37] Second, CENTCOM failed to view the enemy as a thinking adaptive adversary. They assumed the Iraqi's would use the fixed sites predominantly, as they had during the Iran-Iraq war in 1988. Iraq surely endowed the Coalition with a greater capability than it thought Iran would ever possess. They probably knew that use of the fixed facilities was untenable due to the massive air power available. Third, inattention to the Iraqi missile problem prior to the conflict by U.S. intelligence agencies provided a scant database that could not reasonably determine the number of missiles and mobile launchers on hand, the organization of the missile

forces, and the doctrine for operating these mobile forces. Detection and elimination of the mobile TELs was extremely difficult.[38]

What DESERT STORM revealed most clearly was the lack of training, procedures, and doctrine to conduct effective counterforce operations. The whole effort was ad hoc from the start. Without any clear doctrine, the coalition pieced together a methodology that proved inadequate to the situation.[39]

In addition, intelligence and operations had come a long way toward the synergistic approach necessary to optimize operational effectiveness. The plethora of inputs into theater was staggering. When the time came to provide superior and time sensitive fusion of multi-source data to targeteers, the effort faltered. The procedural methodologies and automation support to conduct fusion was immature.[40]

In the end, the success of the coalition efforts against the Iraqi Scud threat was questionable. The number of Scud launches dropped precipitously following the implementation of the counterforce operations against mobile TELs; however, the launches never completely ceased. The intense effort to find the mobile launchers and destroy them certainly had an impact on the launch schedule for the TELs. That the Joint Force Air Component Commander, Lieutenant General Horner, threw up to 1,500 air sorties against Scuds, and related facilities and equipment says volumes of the effort expended to eliminate this threat. This represented about four percent of the total combat sorties flown during the war.[41]

Some lessons learned from peacetime treaty verification strategies and experiences in war are:

- Operational forces must know enemy missile force status, readiness, size, doctrine, operations and system characteristics prior to a conflict.
- Timely dissemination of targetable intelligence information regarding location of mobile launchers and support units is critical to the success of any crisis or wartime operation.
- Joint and service training, doctrine, and procedures must reflect a rigorous and systematic approach to locating and targeting TMs.

IV. Locating High Priority Mobile Targets. Defining the threat, and putting together the disparate pieces of the TM system begins with Intelligence Preparation of the Battlefield (IPB). Because of the vast expanses of land involved, it is usually best to determine where the enemy is not. Eliminating possibilities narrows the scope of the problem, and makes analysis more manageable. This is the philosophy behind negative search theory.

Not surprisingly, negative search theory finds an ally in IPB. IPB (U.S. Army Field Manual 34-130, *Intelligence Preparation of the Battlefield*) covers the areas of negative search in a "systematic, continuous process of analyzing the threat and environment in a specific geographic area."[42] It breaks the component parts of the battlefield problem into bite-sized morsels, and allows the analyst to inductively build the puzzle in a systematic manner.

IPB is a reductionist methodology by design. One difficulty with IPB is that it is adequate for the bigger issue of tactical intelligence, but not quite so good for problems that lie on the periphery; i.e. low intensity conflict, terrorism, or counterforce. A more

systemic approach is necessary to deal with the issue. At a minimum, modification of the basic IPB might prove sufficient. Regardless, Joint Pub 3-01.5, *Doctrine for Joint Theater Missile Defense*, affirms that "Planning for attack operations begins with the IPB process."[43] With this in mind, the intelligence staff must modify IPB to suit the exigencies of counterforce targeting.

Constricting the realm of possibilities open to the enemy is a first step to providing certainty. According to negative search theory there are two ways in which the searcher can accomplish this task. He can either raise the probability of detecting the launcher, or the searcher can reduce the required search effort. The searcher can do this by increasing the launcher's exposure probability, or reduce the search time when the launcher is hidden from view.[44] The second option is the province of negative search theory.

A. Environmental Factors. Carl von Clausewitz, the influential Prussian military theorist wrote that, "Geography and ground can affect military operations in three ways: as an obstacle to the approach, as an impediment to visibility, and as cover from fire."[45] In the first sense, evaluating the terrain of the area of operations and area of interest are critical to determining the probable staging and launching bases as well as hide sites and movement routes between these areas. Based on an evaluation of the threat systems involved, the analyst can determine the areas that the vehicles can traverse, where they can fire, and where they can hide after they fire. This type of analysis is known as negative search. It is the negation of usable space to enemy systems due to their known capabilities and limitations. As the analyst delves into the doctrinal employment of the TM elements, more space drops out of the equation. This iterative denial of space hones the search area

to a more manageable piece. The implication of Clausewitz's second part is that terrain plays a key role in obscuring the observers view of the target. Modern connotations extend to both visual as well as electronic masking. The third meaning imparts a defensive property to terrain if used properly. Even for relatively defenseless TELs and resupply vehicles geography allows a measure of protection.

The intelligence analyst in consonance with the engineer terrain expert must conduct a thorough and accurate terrain analysis of the area of operation (AO) and area of interest (AI). Especially important are factors such as terrain, road access, vegetation, communication networks, and physical limitations of the launcher itself.[46] As mentioned above, the enemy is restricted to certain areas due to the capabilities of the TELs. Negating space based upon terrain considerations identifies possible operating areas. As Sun Tzu pointed out over 2,000 years ago,

> Now the army's disposition of force (*hsing*) is like water. Water's configuration (*hsing*) avoids heights and races downward. The army's disposition of force (*hsing*) avoids the substantial and strikes the vacuous. Water configures (*hsing*) its flow in accord with the terrain.[47]

Vehicle traversibility over various ground compositions and slopes is specific to a particular type of chassis. When evaluating TM launcher and resupply vehicles the analyst must become fully conversant in their capabilities and limitation. For instance, the MAZ-543 transporter-erector-launcher is the primary launch support vehicle for the SS-1B (Scud-A), SS-1C (Scud-B), and SS-12 (Scaleboard) surface-to-surface missiles.[48] It has excellent cross-country mobility. See Appendix D for details on Scud movement attributes.

Placement of artificial obstacles further fences the TEL in to designated areas. A commander cannot afford to waste obstacles, or area denial weapons. He must take careful consideration of where he wants the target to operate, and where the artificial impediments to movement are optimized with respect to target canalization.

A particularly undesirable means of locating launchers is to geolocate their missile plume after they have fired. In doing so the command has abrogated the initiative to the enemy. Besides, now air defense assets must deal with an incoming missile. It provides only an after-the-fact measure of where the launch vehicle was, not where it is. For the intelligence professional plot diagrams and pattern analysis probably will not suffice. The enemy will change his pattern based on success or security considerations. As Chuyev and Mikhaylev, prominent Soviet theorists, point out:

> [I]t would be naive to assume that the enemy, who would also be observing and analyzing our action, would hold to his former offensive tactics (would not change the model of his actions), having seen that, because of the timely adoption of countermeasures by the other side, the success of his offensive operation had become problematic.[49]

The enemy will undoubtedly employ multiple presurveyed launch and hide sites. For these reasons, it is always desirable to locate and destroy the systems before they launch their payload.

Weather can change the environmental dynamics tremendously. Terrain previously trafficable to vehicles becomes impassable, or vice versa. It impacts not only where on the ground the TELs can go, but where and when the launchers can launch. Ground tension changes with precipitation, and incidental seasonal variations, such as types of precipitation and temperature. Bad weather severely restricts the ability of the system to

deliver its payload. Missiles cannot effectively launch in high winds, thunderstorms, or with heavy rains or snows. Weather also impact counterforce operations as well. Whereas cloud cover aids TM launches by minimizing enemy employment of precision guided munitions, it also restricts aerial and overhead reconnaissance and early warning detection of launches. Higher cloud cover is better. It allows increased launch time before detection.[50]

Time of day has a tremendous impact on operations. During low visibility, even allowing for the tremendous advances in infrared and thermal technology, commanders have encountered more difficulties than at clear daylight hours. Iraqi launch systems exploited this deficiency during the Persian Gulf conflict by firing mainly at night.[51]

B. Force Considerations. The analyst must consider numerous factors and issues when approaching the problem of finding deployed TMs. First, the analyst must determine the nature of the force under consideration. What are their doctrine, TTPs, training level, timing, and deployment patterns. The characteristics of the enemy's weapon systems are also of interest; i.e., range, C2, signatures, etc. Second, the intelligence officer must measure the impact of terrain and weather on the way the opponent would like to execute. He cannot necessarily deploy his forces in his preferred manner. In the end, as Sun Tzu would say, "One who knows the enemy and knows himself will not be endangered in a hundred engagements."[52]

Data bases built in peacetime provide numbers, types, ranges, and operating characteristics of missile systems. They also develop training proficiency, organization, doctrine, and TTP for operating the missile forces. This is easier in a non-intrusive way

through treaty verification. If no treaty is in effect, then the database must be built from open source press releases, covert, and clandestine means. Open source publications, conferences, and symposiums provide the bulk of the intelligence regarding foreign capabilities. The most hypothesized means is through airborne and overhead electro-optical and synthetic aperture radar imaging systems. Although the capabilities of such systems is beyond the scope of this monograph, the ability to determine the quantity and type may be their sole benefit. Human intelligence (HUMINT) sources provides not only the data provided by open source material and national technical means, but also the intentions of the force under surveillance.

Databases are generally in various stages of disrepair. They are rarely complete or current. The quality of the databases are dependent wholly on the priority given to the target or nation. Iraq provides the case in point for this as well. Iraq, although not entirely trusted by the United States prior to the Persian Gulf War, was not seen as a major threat. As such, the intelligence community put forth little effort and priority to collection of their TBM capability, doctrine, organization, and equipment.

Equally applicable are friendly capabilities. The enemy's perception of them, play a significant part in determining his courses of action. This is one area that is ill considered in the IPB process. Enemy intentions, objectives, and ways are in large part determined by their appreciation of friendly capabilities. Again, take DESERT STORM as a cogent example. The Iraqi's were aware of the United States' capabilities with regard to signals intelligence. They modified their tactics to reduce the signature of the assets they wished to protect. In this instance, communications over the open air waves were

minimized, and where necessary, one way - from the command to the TEL, and not vice versa.[53] The Iraqi's did, however, employ the Fan Song and End Tray meteorological radars and associated Ball Point radiosonde, but the signals were not a good predictor of launcher location. They were often many kilometers away from the launch point.[54] These are not the only examples, but are satisfactory to make the point.

The Results of IPB analysis are the basis for the targeting process. Attack operations require the rigorous specificity of enemy locations to prosecute. IPB can tell where the enemy probably is, and based on his capabilities, doctrine, and goals where he will likely go. But IPB is only the start.

V. Targeting and Attack Operations. The linkage between intelligence operator and targeteers is critical to prosecution of the mission. Each has a significant part to play in achieving the end: destruction of the enemy target(s). The roles overlap; requiring extensive coordination in all phases of the decide, detect, deliver, and assess (D3A) methodology.[55]

The intelligence staff has a responsibility that goes well beyond the confines of the J-2. It must ensure that credible, accurate, and timely information makes it to the shooters. Beyond that, even, intelligence personnel should intervene to ensure that the information needs of the decision makers are addressed adequately, that valuable information is acted on, and intelligence operations are fully integrated in the operations plan. Planners should introduce measures of effectiveness to evaluate the productiveness of the overall counterforce mission.

Following the D3A methodology, intelligence planners develop the enemy situation as they envision it at some future time, as deemed appropriate by the decision makers. Along with these estimates, the planners determine the enemy's most precious assets, the destruction/neutralization of which would seriously disrupt his plan. These precious quantities, or high value targets (HVT) are presented during the targeting meeting/board for validation and consecration as high priority targets (HPTs). HPTs are those assets that the command wants to destroy as part of its campaign. It is thus that the intelligence planner provides cogent input to the attack operation.

A. Measures of Success: Measures of effectiveness must necessarily include the number and percentage of functional launch platforms, C2 capability, and the ability to resupply the TELs with missiles. As far as available launch platforms, a numerical count of TELs is probably insufficient. A wily foe, such as the Iraqi missile commanders who used numerous dummy launchers, would degrade friendly efforts to derive an accurate count of available TELs and subsequently BDA. Furthermore, since the systems operate semi-autonomously, the reduction of launchers probably would not suffice to incur a severe reduction in operating efficiency. Continuous survival moves by TELs and resupply vehicles resulting from vigilant and aggressive attacks, however, would degrade the efficiency of individual crews significantly. The second measure of effectiveness, reduction or denial of a command and control capability for the TM system, can be measured by inefficient employment and use of TM resources, ineffectual targeting, and sporadic firings. This measure calculates the ability of the enemy to orchestrate his disparate pieces. Lastly, resupply is critical to continuance of the TM effort by the enemy.

Loss of resupply vehicles, and destruction of missile caches and logistics sites are the key measures.

Looking at the problem from a probabilistic viewpoint, the probability of a launcher kill is the product of conditional probabilities of detection (P_D), classification (P_C), geolocation (P_G), acquisition (P_A), and kill (P_K): $P_K = P_D * P_C * P_G * P_A * P_K$. The probability of detection is the product of the detection probability conditioned on the search and the search decision probability.[56] The information associated with the probabilities is highly perishable. Because of this the conditional probabilities the probabilities decay exponentially, and thus the probability of kill does as well. Upon detection, for instance, the probability of correct detection may be very high, but it will rapidly decrease over time so that when it is acted upon the probability is much lower.

The probability of initiating and allocating resources is the C2 measure of effectiveness. Allocation of resources is the primary role of command and control. Given the mission, the decision maker must sift through the data to determine what is going on and apportion the holdings under his control to accomplish the appropriate task. For the J2, this implies optimization of the collection process.[57]

What the command is trying to accomplish is to push the probability of kill close to one, that is to certainty, while the enemy tries to keep it near zero. For this, U.S. forces rely on IPB (negative search), synchronized collection management, dynamic retasking of sensors, sensor-to-shooter links, and information dominance. As one side becomes successful, the other will change TTPs as an attempt to tip the scales in the other direction.

The command group and operations staff must ensure that it articulates what it wants targeted, and to the degree of precision and timeliness. Close interaction with the intelligence staff and other component commanders during the execution phase ensures valuable information is shared to the necessary degree of accuracy.[58]

The formal venue for interaction of the intelligence staff and the targeteers is the targeting meeting, joint targeting board, or joint target coordination board.[59] Whichever name is applied the function remains the same: to select targets for strikes, in priority; and to determine the information requirements to support the prosecution of the target. Before attending the targeting meeting, the intelligence staff takes apart the high value targets (HVTs) identified in the mission analysis portion of the decision making process to determine the ability of sensors to detect, classify, geolocate, and acquisition. This input provides the basis for turning the HVT list into the HPT list.

As is evident from the DESERT SHIELD/DESERT STORM experience, a dedicated effort must be made toward targeting mobile high priority targets. Ad hoc efforts do not provide the expertise and cohesiveness needed to tackle so difficult a problem as this. The TTPs cannot be developed, absorbed, and perfected overnight. It takes time and much exertion. However, once a viable team is assembled, trained, and qualified the process is one of creative analysis. The team must think like the adversary and determine the best placement of assets to accomplish the enemy's mission. Once this is done, the team can focus appropriate assets on the areas of interest.

B. Attack Operations. According to Joint Pub 3-01.5, "During planning, decisions are made concerning targets; conditions for attack; and asset assignment for

surveillance, target acquisition, deconfliction, suppression of enemy air defenses, and attack."[60] These decisions emanate from the Joint Target Coordination Board (JTCB), or whatever forum is established to make them. The decisions are embodied in four specific products. First, the board issues a prioritized target list. Second, the committee matches targets to attack assets in an attack guidance matrix. Third, the board determines the criteria for sensor cueing and triggering of attack assets - target selection standards - based upon timeliness, accuracy, validity, and reliability. Fourth, the group, through the J2, publishes the collection plan focusing intelligence assets on the targets in question.

C. Command and Control. According to that famous military theorist Carl von Clausewitz, "War is the province of uncertainty: three-fourths of those things upon which action in war must be calculated, are hidden more or less in the clouds of great uncertainty."[61] Knowing all that must be known is impossible, however reducing some uncertainty helps pave the way to a reasonable solution. Decision makers instinctively try to abrade the lack of precision to increase the confidence about the choice(s) they must make.

During Operation DESERT STORM the U.S. Air Force implemented command-by-plan[62] through a centralized air tasking order (ATO). About command-by-plan, Thomas J. Czerwinski, a political scientist with the National Defense University, asserted;

> Operating exclusively at the strategic and operational levels of war, it reduces information requirements by focusing on perceived centers of gravity and by honing the associated target lists into prioritized and--increasingly--synchronized and simultaneous operations.[63]

The truth is that organizations and plans are always slower and more inflexible than the events they are intended to control.[64] Eventually the Joint Force Air Component

Commander (JFACC) was forced to revert to combat air patrols (CAPs) to hunt for Scuds due to the inflexibility of the ATO.[65] The inability of the system to forecast Scud locations before ATO publication, or even before launch, forced the necessary changes. Even these modification were insufficient due to sensor limitations on the attack aircraft.[66]

The Scud hunt in the Persian Gulf conflict was essentially a single service enterprise. The U.S. Air Force controlled the primary means of destruction through the ATO. In the future, all services will likely play equally in joint theater missile defense (JTMD). Only decentralized mission execution under joint force commanders can ensure the best tools are brought to bear on the problem. Elaborate joint TTP are required to delineate the functions of each service component command to support intelligence collection, C2, mission planning and execution, and logistics.[67]

The normal response to uncertainty is to increase the information flow. Intuitively, more information means more situational awareness and less fog. This is not necessarily the case. Intelligence data is often incomplete, inconclusive, imprecise, unreliable, conflicting, and more interpretive than fact. What the command does not know, it must make assumptions about. Assumptions regarding enemy capabilities, doctrine, training, and morale provide a means for framing the problem. However, they must be valid. Validity is the key without which planning is ludicrous.[68]

Three assumptions about the TM problem are appropriate to help solve it. First, the target can locate anywhere in the AOR. Its distribution is equivalent over the entire range. Intuitively, one tends to discount this due to the impacts of terrain and weather. Target vehicle cannot traverse certain types of terrain. However, probability analyses

show the distribution over large areas to be fairly distributed throughout; i.e. in all similarly sized regions there are equivalent numbers of targets. Second, the target exposure time will not exceed 120 minutes. This is a somewhat arbitrary interim, however 120 minutes is appropriate for several reasons. TMs instinctively will attempt to get as far away from the location they fired from, while minimizing their exposure time. Geolocation by infrared (IR) sensors of missile exhaust plume is relatively accurate. If the TM remains in the area it will die. As as example, DESERT STORM indicated that Iraqi Scud launchers were in the open for no more than 120 minutes. The third assumption states that the assets available to the command are limited. Again, the obviousness of the statement does not undermine its important truth. Commanders and intelligence officers must husband their intelligence collection resources and focus them where they are needed. These three assumptions will force the analysis and collection planning in certain directions.

VI. Sensor Allocation. Post launch targeting is easier to accomplish. Either infrared launch detection satellites, such as DSP, or over-the-horizon radar will identify the launch and calculate the azimuth and geolocate the launch position. Dynamic retasking of collection assets is possible to identify the TEL and track it to vector in attack assets. Once in the vicinity of last contact by the sensors, an attack systems must detect, locate, identify, track, acquire, and kill the launcher.[69] All of this must be accomplished moving at a high rate of speed, while a cognizant enemy is trying to evade a knowingly imminent attack.[70]

Table 1 shows the remote sensors ability collect the information necessary to discriminate among possible targets, identify the target of interest, and provide reasonably accurate locational data. The numbers indicate the rank order of the intelligence discipline evaluated. A dash means the discipline was ineffective against the target.

Table 1: Post-Launch Collection Capability

	SIGINT	IMINT	IRINT	RADINT	HUMINT
C2	1	2	4	-	3
MISSILE	-	-	1	2	3
GUIDANCE	1	-	-	-	-
LAUNCHER	-	4	1	2	3
SUPPORT	4	2	-	3	1

DESERT STORM proved the inadequacy of the collectors to find and track the TEL, as well as the attackers to locate and discriminate the appropriate target from the ground clutter. Even more infeasible was the search for pre-launch TELs and resupply vehicles. Without the missile plume to serve as an identifiable signal above the background noise, the search was virtually a hunt for a needle in a haystack. Taking the negative search methodology provided previously, the collection manager can focus the limited array of sensors in the best manner to capture critical data about the TELs. Table 2 identifies the collection capability by discipline for pre-launch scenarios. Table 2 provides an indication of the ability to acquire TELs prior to launch.

Table 2: Pre-Launch Collection Capability

	SIGINT	IMINT	IRINT	RADINT	HUMINT
C2	1	2	4	-	3
MISSILE	-	-	-	-	-
GUIDANCE	1	-	-	-	-
LAUNCHER	-	2	-	3	1
SUPPORT	4	2	-	3	1

There were some sensor systems success stories, albeit not complete, that lend themselves to further development. On the side of stand alone cueing system - that is, systems that cue other systems for targeting purposes - first among equals during the Persian Gulf conflict was the special forces teams. Inserted deep behind enemy lines to locate Scuds, they provided invaluable service in finding launchers.[71] Very few definitive sources can do all of the intelligence collection, analysis, and targeting functions right from their location. Special forces can. The down side of the special forces team is the slow response time and the limited field of view. Unattended ground sensors, such as the remotely emplaced battlefield sensor system (REMBASS) provide term surveillance 24-hours per day, but do not yet have the acuity to vector attack assets. Unmanned aerial vehicles (UAVs) provide an excellent tool for the operational commander to provide long dwell surveillance over critical named areas of interest/target areas of interest (NAIs/TAIs).

Cued assets include the Joint Surveillance and Target Acquisition Reconnaissance System (JSTARS), U-2 Advanced Synthetic Aperture Radar System (ASARS), and easily retasked systems like the UAV. These assets have the benefit of providing greater identification and tracking.

Now that the analyst has determined the probable areas where TM systems are deployed, or at least the location where they are unlikely, he coordinates with the collection manager to focus assets to begin the search. Focusing the sensor array against the TM target set requires dynamic and flexible application of the scarce resources available. Collection management doctrine for the U.S. Army is embodied in FM 34-2,

Collection Management and Synchronization Planning. None is specifically delineated in the joint community, although broad guidance is provided in Joint Pub 2.0, *Joint Doctrine for Intelligence Support to Operations*. To delineate this segment of the TM challenge from the previous writings, the author will refer to intelligence collection as positive search. Search theory provides the basis for this effort.

A. Search Theory. Search and detection theory is not only the latest, but also the most rigorous, approach applied to the TM challenge. It actually has a long and proven history of providing a paradigm for developing successful search techniques for U.S. Navy anti-submarine warfare (ASW) efforts.[72] Regardless of the incongruities between the operations of submarine and TM forces, there is enough similarities between the two to allow the use of search and detection theory as a useful framework for conducting analysis and intelligence collection management for the TM problem. Essentially search theory holds that the probability of detection of a mobile launcher is a direct result of several factors: the probability that the target is exposed to potential sensor coverage, and the amount of passes required for a sensor to acquire a target (coverage ratio). We can show that the greater the exposure the more likely the detection. Figure 4 above illustrates this dynamic quite clearly.

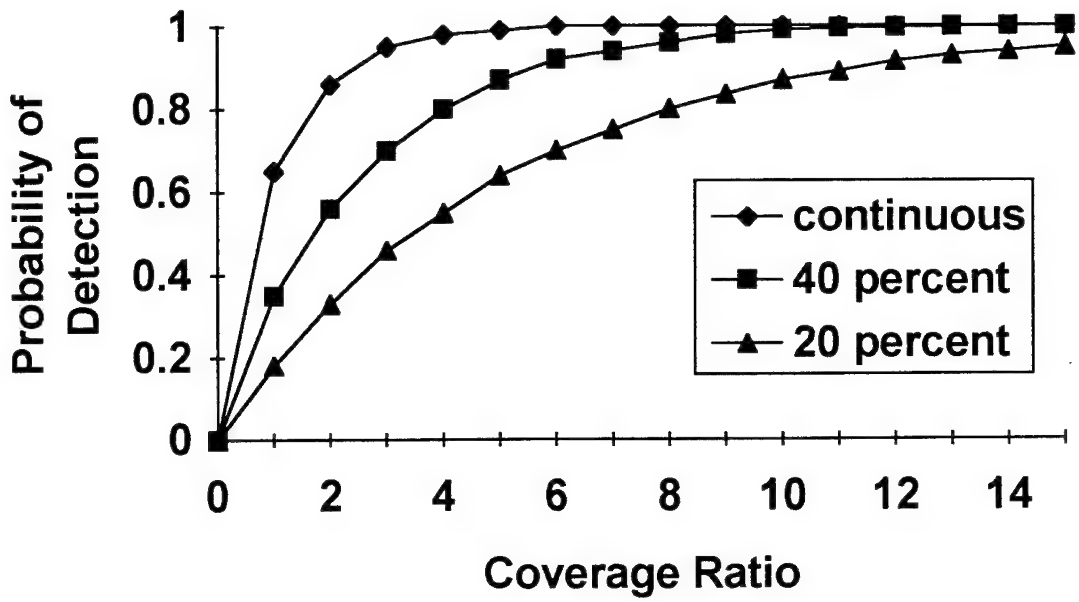

Figure 4. Deterministic Exposure Proportions.[73]

To increase the coverage ratio (z = WL/A) we must accomplish either of three things: increase the sweep width, increase the search length, or decrease the effective area searched.[74] The sweep width, or field of view (W) is a relationship among the sensor type, platform speed and altitude, environmental and geographic factors, and operator proficiency. The implication here is that it is critical to match the sensor to the particular mission, environment, terrain, and time of day. Generally, slower platforms obtain better sweep width due to their ability to discriminate objects better. However, there is a tradeoff between the coverage desired, represented by speed, and the sweep width. Total search length (L) equates to search time. This is obvious, since the time equals total length divided by platform velocity. Greater dwell time means increased probability of detection. The search area (A) is a component of the IPB process. The more refined the analysis, the greater the probability of detection. Negative search and the proper use of

artificial obstacles tends to constrict the search area, thus increasing the probability of detection by the searchers.[75]

If the analyst knows with a high degree of confidence, based upon his previous IPB, what the effective operating area for the target is, then the collection manager can use the coverage area formula to assist in determining the best systems to cover the zone. It does not, however, tell him the appropriate collection asset to use based on sensor capability. He must utilize the best mixture of collectors within his means to increase the probability of detection.

B. Collection Management. Determining the intelligence means (sensors) and ways (collection strategy) to achieve the ends (satisfy requirements) is the province of the collection manager. He is responsible for the allocation of resources to locate the target(s) within the parameters established by the targeting board: meeting the target selection standards, coordinating the information flow to the attack assets, and determining the effectiveness of strikes. Given the measures of performance for collection assets - timeliness, coverage, accuracy, and adequacy - it is quite possible to rank order collection systems as to their value for a particular mission.[76] Generally, it is clear from Table 3 that no intelligence collection discipline holds primacy over the others. What is evident is that a synergistic, considered employment of the various discipline systems will provide the best coverage.

Table 3: Overall Scores of Collection Means for TM Detection.

	SIGINT	IMINT	IRINT	RADINT	HUMINT
TIMELINESS	2	4	3	1	5
COVERAGE	1	4	1	3	5
ACCURACY	4	3	5	2	1
ADEQUACY	5	3	2	4	1

Meshing all of the collection means together into a coherent, synchronized plan takes an inordinate amount of skill and patience. It does not come about by simply slapping an intelligence synchronization matrix together. Capabilities and limitations of the sensors and their associated bus must be weighed.

The fact is that there are too many taskings for the sensors available. The sensor mix is also important. The art is in the proper combination of available assets, with regard to target signature, and geography and environment factors. The collection manager must ensure the sensor mix maximizes the probabilities of detection, classification, and geolocation.

The objective is to increase the probability of detection. As was stated previously, the two ways to accomplish this were to reduce the search area or increase the sensor capability. We cannot readily increase the capability of the sensor suite, but we can effectively reduce the search area further by mixing the collectors in an optimal pattern. Using the NAIs and TAIs established in IPB, the collection manager can ensure continuous coverage, using appropriate sensors, of the most likely areas in which a TM component will pass. Once identified, dynamic retasking will focus on the last sighting to attempt reacquisition, track, locate, and identify the target for cueing of attack assets.

> [T]hree potential benefits from the dynamic allocation of sensor resources are as follows: enhanced performance, freeing resources for other tasks or even eliminating some sensors, and enhanced reliability because of redundancy. A tradeoff between the first two benefits usually exists. The sensor resources are used either for improving performance or are released for other uses. The third benefit results from the involvement of more than one sensor. If one sensor fails, tracking can still continue, even though the performance deteriorates.[77]

In this way the loop is closed. From analysis to targeting to active search to confirmation of our analysis and cueing of attack assets.

Geographic diversity of sensors is an important concept. The impact of the spatial configuration on position estimation is well known. In some systems using sensors for location, a concept known as Geographic Dilution of Position (GDOP) is used to designate some deleterious effects, such as error blowup when the target is on the baseline of the two sensors.

> When the objective is to destroy the launcher by estimating the launch point from the track, we must be able to respond before the launcher is moved. Obtaining the best results entails a delicate balance between a swift response and accuracy in pinpointing the launcher....[E]ven a single measurement from a second sensor improves the accuracy of the estimate dramatically. Geographic diversity is the source of this improvement.[78]

Detection, as alluded to previously, is not the sole goal of collection. This classification issue is particularly perplexing. On the one hand the greater the FOV or search length, the greater the coverage ratio and thus the detection probability. Alternatively, the larger the FOV and search length, the less classification ability is inherent in the system. Orchestration of assets provides for complementary employment of wide area search (high probability of detection), and small FOV (high probability of classification) working in concert.

Even harder to distiguish is the dummy launcher. DESERT STORM provided stark illustrations of the difficulty in determining between real and imitation launchers. Little improvement in sensor classification capabilities appears on the horizon to counter the dummy vehicle/missile issue. Perhaps the research and development community needs to pursue new realms of sensor applications in areas such as mass differential, olfactory,

gustatory, tactile, thermal, or electromagnetic.[79] This technology may also prove effective in classification between WMD and conventional weapons.

C. Information Management. The amount of intelligence data that floods joint staff is overwhelming. Even more profound is that more of it is lost due to inadequate receiving nodes and interoperability between intelligence, and C2 systems. Finding ways to link all of the interested parties will substantially reduce the information wastage occurring now. Improving interoperability will not, however increase the coverage area.[80]

Single source information requires fusing. Data fusion always helps, at least conceptually, although it is not necessarily practical. Theoretically, obtaining data from additional sensors improves performance, even if the quality of the additional data is poor. The resultant effect is to increase the coverage ratio and thus the probability of detection. If the sensors are unsynchronized, the time interval between updates is reduced and this results in improved accuracy between updates. Having the data interleaved is preferable.[81]

The communication bandwidth and the computing power necessary to move this data around and manipulate it are tremendous. Not just that, but the algorithms to interleave information and present it meaningfully are intricate. Planning and training before conflict is critical for execution in war.

VII. Conclusions. Continued and simultaneous proliferation of TM and WMD items has sent shock waves through the developed world. Now countries with meager means or unstable governments can strike a strategic blow to the heart of some of the more

advanced world powers. This has operational and even strategic implications for United States regional and collective security.

The issue becomes ever more complicated as time moves on. Increased precision and range, inadequate operational and strategic defenses, poor understanding of threat TM organization, doctrine, training, TTPs, and equipment, and continued difficulties grappling with joint theater missile defense are the causes of this concern. Only by working through the issues can the U.S. and its allies alleviate some of the angst.

Historically, the U.S. dealt with counterforce operations only twice. In WWII the allies attempted attack operations but came up short. Occupation of the launch sites ended the problem before it was solved. DESERT STORM proved that TMs are formidable weapons and could outwit arguably the world's best air force and intelligence system. The Cold War spurred the technology that is instrumental in any detection operation: national technical means. It built the databases during pre-hostilities and provided quality intelligence information during war.

Three primary factors come into play when dealing with intelligence and counterforce operations. First, the proper application of intelligence preparation of the battlefield assesses the enemy and environment for probable launch, storage, transit, and hide locations. Second, sensor placement, integration and synergy verifies or denies the IPB and tracks suspected TELs or resupply vehicles. And third, timely cueing of attack platforms for the pursuit of a counterforce mission are critical to completion of the mission. Without the coordination of all services and assets toward a common objective, using joint tactics, techniques, and procedures the effort to thwart TM treats before launch

will fail. If the 'Scud Hunt' during the Gulf War showed nothing else, it was the need for a unified and rigorous methodology, and the cooperation of all the service component commanders and supporting agencies. But the 'Scud Hunt' failed for many of the reasons previously illustrated.

That the coalition forces failed in DESERT STORM to stop the Scud attacks is true. The reasons are many and varied. First, that the threat from Scud or their variants was not appreciated by the leadership is well known. General Schwarzkopf considered them terror weapons, and tactically and operationally insignificant because of their poor accuracy. He had not fully considered the impact from the political leadership of the U.S., Saudi Arabia, and Israel. This pressure turned the affair into a high priority hunt, much as it had in Eisenhower's search for V1 and V2 sites and related facilities in Europe. Second, the intelligence community failed to follow the development of Iraqi missile organization, equipment, doctrine, training, and tactics, techniques, and procedures. Perhaps, it thought the procedures would stay the same as it had in the Iran-Iraq war that ended two years before. They did not. Certainly, the intelligence community did not account for the Iraqi perception of U.S. intelligence and attack capabilities. Iraq, in effect, successfully broke with its past and deployed almost entirely mobile launch operations. They modified the whole launch sequence to shorten the time to firing and dispersal following delivery. Albeit, it made the system much less accurate, Saddam Hussein was not so much interested in the physical effects as the political and morale impact. In this, he almost succeeded in tearing the coalition apart by bringing Israel to the brink of offensive action. Third, neither Central Command nor the strategic community understood how the Scud

problem should be prosecuted. It was a seat of the pants effort pieced together using the JFACC "Black Hole" as the coordinating hub. JTBM doctrine for attack and intelligence operation was not written until after the conflict, and presumably because of the Persian Gulf deficiencies in these affairs. Although the tools to solve the problem were at hand, for the most part, the means to piece them together can and should never be done in war. It is a recipe for disaster.

The key to counterforce operations is the detection, geolocation, tracking, and cueing of the attack assets by intelligence systems. And the crux of intelligence operations is the skillful determination of most likely areas where TMs are located, and the adroit application of sensors to detect and track the target. To increase the probability of detection, the collection manager must increase the coverage ratio. This is raised by placing more coverage over the suspected areas.

Locating TMs is possible through the proper application of IPB, search theory, and sensor allocation. The methodology is solid. But a flexible and directed architecture must get the information to those who need it.

As Stephen Mann, Deputy Chief of Mission at the U.S. Embassy in Colombo, Sri Lanka warned, "Once we have achieved a ... framework that is logically consistent and provides a comprehensive, predictive description of war, we can no longer fully trust that framework."[82] It is the observers impact upon the environment under observation that changes it. This is certainly true of the TM threat. The framework provides a means to work through the TM problem from an intelligence support to targeting perspective.

However, it allows enough flexibility to anticipate the vagaries of the capricious battlefield, and enemy modifications to capabilities and intentions.

Appendix A: Glossary of Terms

Area of Operations (AO): An operational area defined by the joint force commander for land and naval forces. Areas of operation do not typically encompass the entire operational area of the joint force commander, but should be large enough for component commanders to accomplish their missions and protect their forces.[83]

Area of Interest (AI): That area of concern to the commander, including the area of influence, areas adjacent thereto, and extending into enemy territory to the objectives of current or planned operations. This area also includes areas occupied by enemy forces who could jeopardize the accomplishment of the mission.[84]

Attack Operations. Operations taken to destroy, disrupt, or neutralize theater missile launch platforms and their supporting structures and systems.[85]

Circular Error Probable (CEP): An indicator of the delivery accuracy of a weapon system, used as a factor in determining probable damage to a target. It is the radius of a circle within which half of a missile's projectiles are expected to fall. Also called CEP.[86]

Counterforce: a strategy to employ forces to destroy, or render impotent, military capabilities of an enemy force.[87]

Global Navigation Satellite System (GLOSNASS): A 21 satellite constellation in three planes, 120° apart, designed to provide accurate positioning data. It was developed by the USSR, and is now operated and maintained by Russia. GLOSNASS operates in the frequency band 1602.2 to 1615.9 MHz at a wavelength of 19cm. Recently, the system has logged performance in the range 17 meters spherical error probability (SEP).[88]

Global Positioning Satellite (GPS): A U.S. 21 satellite constellation in polar orbit. It operates in two frequencies 1575.42 MHz for civilian applications, and 1227.60 MHz for military use only. The system can provide accuracies up to 16 meters SEP.[89]

High-Payoff Target (HPT): High value targets whose loss will contribute to the success of the friendly course of action (COA).[90]

High-Value Target (HVT): Assets that the threat commander requires for the successful completion of a specific COA.[91]

Intelligence Preparation of the Battlefield (IPB): A systematic, continuous process of analyzing the threat and environment in a specific geographic area. It is designed to support staff estimates and military decision making.[92]

Joint Force Air Component Commander (JFACC): Derives authority from the joint force commander who has the authority to exercise operational control, assign missions, direct coordination among subordinate commanders, redirect and organize forces to ensure unity of effort in the accomplishment of the overall mission. The joint force commander will normally designate a joint force air component commander. The joint force air component commander's responsibilities will be assigned by the joint force commander (normally these would include, but not be limited to, planning, coordination, allocation, and tasking based on the joint force commander's apportionment decision). Using the joint force commander's guidance and authority, and in coordination with other Service component commanders and other assigned or supporting commanders, the joint force air component commander will recommend to the joint force commander apportionment of air sorties to various missions or geographic areas.[93]

Joint Target Coordination Board (JTCB): A group formed by the joint force commander to accomplish broad targeting oversight functions that may include but are not limited to coordinating targeting information, providing targeting guidance and priorities, and preparing and/or refining joint target lists. The board is normally comprised of representatives from the joint force staff, all components, and if required, component subordinate units. Also called JTCB. See also joint target list.[94]

Joint Theater Missile Defense (JTMD): The integration of joint force capabilities to destroy enemy theater missiles in flight or prior to launch or to otherwise disrupt the enemy's theater missile operations through an appropriate mix of mutually supportive passive missile defense; active missile defense; attack operations; and supporting command, control, communications, computers, and intelligence measures. Enemy theater missiles are those which are aimed at targets outside the continental United States.[95]

Named Area of Interest (NAI): The geographical area where information that will satisfy a specific information requirement can be collected. NAI are usually selected to capture indications of threat COAs but also may be related to conditions of the battelfield.[96]

Target Area of Interest (TAI): The geographical area where HVTs can be acquired and engaged by friendly forces. Not all TAIs will form part of the friendly COA; only TAIs associated with HPTs are of interest to the staff. These are identified during staff planning and wargaming. TAIs differ from engagement areas in degree. Engagement areas plan for the use of all available weapons; TAIs might be engaged by a single weapon.[97]

Theater Missile (TM): Ballistic missiles, cruise missiles, and air-to-surface missiles whose targets are within a given theater of operation. Short range, nonnuclear, direct fire missiles, bombs, and rockets such as Maverick or wire-guided missiles are not considered "theater missiles".[98]

Appendix B: Ballistic and Cruise Missile Capabilities[99]

Country	BMs	LACMs	ASCMs	NBC Wpns
Afghanistan	USED	no	no	
Algeria	deploy	no	deploy	
Angola	no	no	deploy	
Argentina	Produce[a]	capability	USED	N (cap)
Australia	no	no	deploy	
Azerbaijan	deploy	no	no	
Bahrain	no	no	deploy	
Bangladesh	no	no	deploy	
Belarus	deploy	deploy	deploy	
Belgium	no	no	deploy	
Brazil	capability	no	deploy	N (cap)
Brunei	no	no	deploy	
Bulgaria	deploy	no	deploy	
Cameroon	no	no	deploy	
Canada	no	no	deploy	
Chile	no	no	deploy	
China	produce[a, b, c]	future cap.	produce	N, B, C
Colombia	no	no	deploy	
Croatia	deploy ?	no	deploy	
Cuba	no	no	deploy	
Czech Rep.	deploy	no	no	
Denmark	no	no	deploy	
Ecuador	no	no	deploy	
Egypt	USED	no	USED	C
Eritrea	no	no	deploy	
Finland	no	no	deploy	
France	produce[a, b, c]	produce	produce	N
Georgia	deploy	no	no	
Germany	no	produce	produce	
Greece	no	no	deploy	
Hungary	deploy	no	no	
India	produce[a,b,c]	produce	USED	N, B (cap.), C
Indonesia	no	no	deploy	
Iran	USED[a]	capability	USED	N (prog.), B (prog.), C
Iraq	USED[a]	produce	USED	N, B, C (all prohibited)
Israel	produce[a,b]	produce	USED	N, B (cap.), C
Italy	no	no	produce	
Japan	capability[a,b,c]	no	produce	N (cap.)
Kazakhstan	deploy[a,c]	deploy	deploy	N, (Russian control)

Country	BMs	LACMs	ASCMs	NBC Wpns
Kenya	no	no	deploy	
South Korea	produce	no	deploy	N (cap.), B (cap.)
North Korea	produce[a,b]	future cap.	produce	N, B, C (programs)
Kuwait	no	no	deploy	
Libya	USED	no	deploy	N (prog.), B (prog.), C
Malaysia	no	no	deploy	
Morocco	no	no	deploy	
Netherlands	no	no	deploy	
New Zealand	no	no	deploy	
Nigeria	no	no	deploy	
Norway	no	no	produce	
Oman	no	no	deploy	
Pakistan	produce	no	deploy	N, B (prog.), C
Peru	no	no	deploy	
Poland	deploy	no	deploy	
Portugal	no	no	deploy	
Qatar	no	no	deploy	
Romania	deploy	no	deploy	
Russia	produce	produce	produce	N, B, C
Saudi Arabia	deploy	no	deploy	
Serbia	developing	no	deploy	
Singapore	no	no	deploy	
Slovakia	deploy	no	no	
Somalia	no	no	deploy	
South Africa	produce	capability	produce	N (dismantled), B (prog.), C
Spain	capability	no	deploy	
Sweden	no	produce	produce	
Syria	deploy	no	deploy	B, C
Taiwan	produce	produce	produce	N (cap.), B (prog.) C (cap')
Thailand	no	no	deploy	
Tunisia	no	no	deploy	
Turkey	no	no	deploy	
Ukraine	deploy	deploy	deploy	N
U.A.E.	deploy	no	deploy	
UK	deploy	capability	USED	N
United States	produce	USED	USED	N, C (being dismantled)
Venezuela	no	no	deploy	
Vietnam	deploy	no	deploy	C
Yemen	deploy	no	deploy	

[a] Produce, deploy or have the capability to produce medium range ballistic missiles (800 - 2,399 km).
[b] Produce, deploy or have the capability to produce intermediate range ballistic missiles (2,399- 5,499 km).
[c] Produce, deploy or have the capability to produce intercontinental range ballistic missiles (5,500 km+).

Appendix C: Ballistic and Cruise Missile Inventories.[100]

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
AFGHANISTAN					
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
ALGERIA					
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
SS-N-2b STYX (P-15)	ASCM	Russia	50	513	I
ANGOLA					
SS-N-2b STYX (P-15)	ASCM	Russia	50	513	I
ARGENTINA					
ALACRAN	SRBM	Domestic	200	500	I
CONDOR 2 (Badr 2000)	MRBM	Domestic	900	450	T
EXOCET (MM-38)	ASCM	France	42	165	I
EXOCET (AM-39)	ASCM	France	50	165	I
EXOCET (SM-39)	ASCM	France	50	165	I
EXOCET (MM-40)	ASCM	France	70	165	I
MQ-2 (BIGUA)	LACM	Domestic	900	70	D
AUSTRALIA					
AGM-84A (HARPOON)	ASCM	USA	120	220	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
AZERBAIJAN					
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
BAHRAIN					
EXOCET (MM-40)	ASCM	France	70	165	I
BANGLADESH					
HY-2 (SILKWORM)	ASCM	China	95	513	I
FL-1	ASCM	China	40	513	I
BELARUS					
SS-21 SCARAB (Tochka)	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
SS-25 SICKLER (S-12)	MICBM	Returned to Russia, Nov 1996			
AS-4 KITCHEN (Kh-22)	LA/ASCM	Russia	400	1,000 / N	I
AS-6 KINGFISHKSR-5	LA/ASCM	Russia	400	1,000 / N	I
BELGIUM					
EXOCET (MM-40)	ASCM	France	70	165	I
BRAZIL					
MB / EE 150	SRBM	Domestic	150	500	T
SS-300	SRBM	Domestic	300	450	T
SS-600	SRBM	Domestic	600	500	T
SS-1000	SRBM	Domestic	1,200	nk	T
VLS	SLV	Domestic	5,000	500	D
SM-70 (BARRACUDA)	ASCM	Domestic	70	nk	D
EXOCET (MM-40)	ASCM	France	70	165	I

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
BRUNEI					
EXOCET (MM-38)	ASCM	France	42	165	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
BULGARIA					
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
AS-1 KENNEL (Kh-28)	ASCM	Russia	100	1,000	I
AS-9 KYLE	ASCM	Russia	90	200	I
SS-N-2b STYX (P-15)	ASCM	Russia	50	513	I
CAMEROON					
EXOCET (MM-40)	ASCM	France	70	165	I
CANADA					
AGM-84A (HARPOON)	ASCM	USA	120	220	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
CHILE					
EXOCET (MM-38)	ASCM	France	42	165	I
GABRIEL II	ASCM	Israel	36	100	I
CHINA					
CSS-2 (DF-3/3A)	IRBM	Domestic	2,800	2,150/1 RV	I
CSS-3 (DF-4)	IRBM	Domestic	4,750	1 RV	I
CSS-4 (DF-5 5A)	ICBM	Domestic	13,000	1 RV	I
CSS-5 (DF-21/21A)	MRBM	Domestic	1,800	1 RV	I
CSS-8 (M-7)	SRBM	Domestic	160	190	I
CSS-N-3 (JL-1)	SLBM	Domestic	1,700	1 RV	I
DF-11 (M-11/CSS-7)	SRBM	Domestic	300	800	I
DF-15 (M-9/CSS-6)	SRBM	Domestic	600	950	I
DF-25	MRBM	Domestic	1,700	2,000	D
DF-31	ICBM	Domestic	8,000	1 RV	T
DF-41	ICBM	Domestic	12,000	MIRVed	D
JL-2	SLBM	Domestic	8,000	1 RV	D
SY-1 / HY-1	ASCM	Domestic	50	513	I
HY-2 (SILKWORM)	ASCM	Domestic	95	513	I
HY-3 / C-301	ASCM	Domestic	100	500	D
HY-4 / C-201	ASCM	Domestic	150	500	I
FL-1	ASCM	Domestic	40	513	I
FL-2 / SY-2	ASCM	Domestic	50	365	I
C-101	ASCM	Domestic	50	400	I
C-601	ASCM	Domestic	95	500	I
YJ-1 / C-801	ASCM	Domestic	40	165	I
YJ-2 / C-802	ASCM	Domestic	95	165	I
C-802 (mod)	AS/LACM	Domestic	180	nk	D

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
COLOMBIA					
EXOCET (MM-40)	ASCM	France	70	165	I
CROATIA					
SA-2 (modified)	BSRBM	Domestic	80	130	I
SS-N-2b STYX (P-20)	ASCM	Russia	50	513	I
RBS-15	ASCM	Sweden	90	250	I
CUBA					
SS-N-2b STYX (P-20)	ASCM	Russia	50	513	I
AS-1 KENNEL (KS-1)	ASCM	Russia	100	1,000	I
CZECH REPUBLIC					
SS-21 SCARAB (Tochka)	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
DENMARK					
RGM-84A (HARPOON)	ASCM	USA	120	220	I
ECUADOR					
EXOCET (MM-38)	ASCM	France	42	165	I
EXOCET (MM-40)	ASCM	France	70	165	I
GABRIEL II	ASCM	Israel	36	100	I
EGYPT					
SS-1 SCUD B (R-17)	SRBM	NK/Russia	300	985	I
PROJECT-T	SRBM	Dom./NK	450	nk	I
VECTOR (Badr 2000)	MRBM	Domestic	900	450	T
ARMAT	ASCM	France	90	160	I
AS-1 KENNEL (KS-1)	ASCM	Russia	100	1,000	I
AS-5 KELT (KSR-2)	ASCM	Russia	180	1,000	I
EXOCET (AM-39)	ASCM	France	50	165	I
FL-1	ASCM	China	40	513	I
HY-2 (SILKWORM)	ASCM	China	95	513	I
SS-N-2a STYX (P-15)	ASCM	Russia	43	513	I
OTOMAT (Mk 1)	ASCM	Italy	80	210	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
ERITREA					
SS-N-2a STYX (P-15)	ASCM	Russia	43	513	I
FINLAND					
RBS-15	ASCM	Sweden	90	250	I
SS-N-2b STYX (P-15)	ASCM	Russia	50	513	I

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
FRANCE					
HADES	SRBM	Domestic	480	400	I
SSB S-3D	IRBM	Domestic	3,500	1RV	R
MSBS (M-4A/B)	SLBM	Domestic	4,000	6 RV	I
MSBS (M-45)	SLBM	Domestic	6,000	6 RV	I
MSBS (M-51)	SLBM	Domestic	8,000	6 RV	D
EXOCET (MM-38)	ASCM	Domestic	42	165	I
EXOCET (AM-39)	ASCM	Domestic	50	165	I
EXOCET (SM-39)	ASCM	Domestic	50	165	I
EXOCET (MM-40)	ASCM	Domestic	70	165	I
ARMAT	ASCM	Domestic	90	160	I
APACHE	ASCM	Domestic	150	520	T
ANS	ASCM	Domestic	180	180	C
ANL	ASCM	Domestic	50	180	C
ASMP	LACM	Domestic	300	300ktN	I
APACHE (SCALP)	LACM	Domestic	400	+400	D
ASURA	LACM	Domestic	400	240	D
ASLP	LACM	Domestic	1,300	N	D
GEORGIA					
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
GERMANY					
EXOCET (MM-38)	ASCM	France	42	165	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
KORMORAN 1	ASCM	Domestic	35	165	I
KORMORAN 2	ASCM	Domestic	60	220	I
KEPD 50 / 250	LACM	Domestic	50	250nk	D
GREECE					
PENGUIN (Mk 3)	SRBM	Norway	300	985	I
EXOCET (MM-38)	ASCM	France	42	165	I
AGM-84A (HARPOON)	ASCM	USA	120	220	I
HUNGARY					
SS-21 SCARAB	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
INDIA					
PRITHVI 1 (SS-150)	SRBM	Domestic	150	1,000	I
PRITHVI 2 (SS-250)	SRBM	Domestic	250	500	I
PRITHVI 3 (SS-350)	SRBM	Domestic	350	500	D
SAGRIKA	SLBM	Domestic	300	nk	D
AGNI	IRBM	Domestic	2,500	1,000	P
ASLV	SLV	Domestic	4,500	1,000	I
GSLV	SLV	Domestic	14,000	nk	D
PSLV	SLV	Domestic	8,000	nk	D
EXOCET (AM-39)	ASCM	France	50	165	I
KORAL (SS-N-22)	ASCM	Dom/Russia	110	500	D
SS-N-2c (STYX)	ASCM	Russia	100	513	I
SS-N-2d (STYX)	ASCM	Russia	85	513	I
SS-N-7 (STARBRIGHT)	ASCM	Russia	65	500	I
SEA EAGLE	ASCM	UK	110	230	I
LAKSHYA	LACM	Domestic	500	200	I
INDONESIA					
EXOCET (MM-38)	ASCM	France	42	165	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
IRAN					
MUSHAK 120 (IRAN 130)	BSRBM	Domestic	120	150	I
MUSHAK 160	SRBM	Domestic	150	190	D
CSS-8 (M-7)	SRBM	China	160	190	I
MUSHAK 200	SRBM	Domestic	200	500	D
M-11 (Tondar 68)	SRBM	China	300	800	I
SS-1 SCUD B (R-17)	SRBM	NK/Domestic	320	985	I
SS-1 SCUD C	SRBM	NK	550	500	I
NODONG 1	MRBM	NK	1,000	1,000	T
AS-11 KILTER (Kh-58)	AS/LACM	Russia	50	130	I
AS-9 KYLE (Kh-28)	ASCM	Russia	90	200	I
YJ-2 / C-802	ASCM	China	95	165	I
HY-2 (SILKWORM)	ASCM	China	95	513	I
SS-N-22 SUNBURN (3M80)	ASCM	Ukraine	110	500	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
HY-4 / C-201	ASCM	China	150	500	I
SILKWORM (mod)	ASCM	Domestic/NK	450	500	D

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
IRAQ					
ABABIL 100	SRBM	Domestic	150	nk	D
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	P
AL HUSSEIN	SRBM	Domestic	600+	250	P
AL HIJARAH	SRBM	Domestic	650+	250	P
BADR 2000	MRBM	Domestic	900	450	P
AL ABBAS	MRBM	Domestic	900+	350	T
TAMMUZ 1	MRBM	Domestic	2,000	750	T
AL ABID	SLV/IRBM	Domestic	2,500+	nk	T
YJ-1 / C-801	ASCM	China	40	165	I
AS-11 KILTER (Kh-38)	AS/LACM	Russia	50	130	I
EXOCET (AM-39)	ASCM	France	50	165	I
FAW 70	ASCM	Domestic	70	500	I
ARMAT	ASCM	France	90	160	I
HY-2 (SILKWORM)	ASCM	China	95	513	I
C-601 Nisan 28	ASCM	China	95	500	I
FAW 150	ASCM	Domestic	150	500	I
AS-6 KINGFISH (KSR-5)	AS/LACM	Russia	180	1,000	I
FAW 200	ASCM	Domestic	200	500	I
AS-4 KITCHEN (Kh-22)	AS/LACM	Russia	400	1,000	I
AS-5 KELT (KSR-2)	AS/LACM	Russia	400	1,000	I
ABABIL	LACM	Domestic	500	250	D?
ISRAEL					
LANCE (MGM-52)	BSRBM	USA	130	450	I
JERICHO 1 (YA-1)	SRBM	Domestic	500	500	I
JERICHO 2 (YA-2)	MRBM	Domestic	1,500	1,000	I
SHAVIT	SLV	Domestic	4,500	1,100	I
GABRIEL II	ASCM	Domestic	36	100	I
GABRIEL III	ASCM	Domestic	36	150	I
POPEYE	LACM	Domestic	100	395	I
AGM-84A (HARPOON)	ASCM	USA	120	220	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
UGM-84A (HARPOON)	ASCM	USA	120	220	I
GABRIEL IV	ASCM	Domestic	200	240	I
DELILA	HHD	Domestic	400	54	I
DELILAH (mod)	LACM	Domestic	400	450	D
HARPY	HD	Domestic	500	nk	I
ITALY					
KORMORAN 2	ASCM	Germany	60	220	I
OTOMAT (Mk 2)	ASCM	Domestic	180	210	I

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
JAPAN					
M-3	SLV	Domestic	4,000	500	C
H-1	SLV	Domestic	12,000	500+	C
H-2	SLV	Domestic	15,000	4,000	C
ASM-1 (TYPE 80)	ASCM	Domestic	50	150	I
ASM-2 (TYPE 80)	ASCM	Domestic	150	150	D
AGM-84A (HARPOON)	ASCM	USA	120	220	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
UGM-84A (HARPOON)	ASCM	USA	120	220	I
SSM-1	ASCM	Domestic	150	250	I
KAZAKHSTAN					
SS-21 (SCARAB)	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
AS-4 KITCHEN (Kh-22)	LA/ASCM	Russia	400	1,000N	I
KENYA					
GABRIEL II	ASCM	Israel	36	100	I
OTOMAT Mk 2	ASCM	Italy	180	210	I
NORTH KOREA					
SCUD Mod B (R-17)	SRBM	Domestic	320	985	I
SCUD C	SRBM	Domestic	550	500	I
NODONG 1 (ND-1)	MRBM	Domestic	1,000	1,000	E
NODONG 2 (ND-2)	MRBM	Domestic	1,500	1,000	D
TAEPODONG 1 (TD-1)	MRBM	Domestic	2,000	1,000	D
TAEPODONG 2 (TD-2)	IRBM	Domestic	3,500	1,000	D
SS-N-2a STYX (P-15)	ASCM	Russia	43	513	I
HY-2 (SILKWORM)	ASCM	China	95	513	I
SILKWORM (modified)	ASCM	Domestic	160	+nk	D
SOUTH KOREA					
NHK-1	SRBM	Domestic	250	300	I
KSR-1	SRBM	Domestic	150	200	D
NHK-AHYON MU	SRBM	Domestic	180	300	D
EXOCET AM-38	ASCM	France	42	165	I
AGM-84A HARPOON	ASCM	USA	120	220	I
RGM-84A HARPOON	ASCM	USA	120	220	I
KUWAIT					
ARMAT	ASCM	France	90	160	I
EXOCET (AM-39)	ASCM	France	50	165	I
EXOCET (MM-40)	ASCM	France	70	165	I
AGM-84A (HARPOON)	ASCM	USA	120	220	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
LIBYA					
SS-21 (SCARAB)	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
SCUD C	SRBM	North Korea	550	500	I
AL FATTAH (Ittisalt)	MRBM	Domestic	950	500	D
EXOCET (AM-39)	ASCM	France	50	165	I
SS-N-2c STYX (P-20)	ASCM	Russia	85	513	I
OTOMAT (Mk 2)	ASCM	Italy	180	210	I
MALAYSIA					
EXOCET (MM-38)	ASCM	France	42	165	I
MOROCCO					
EXOCET (MM-38)	ASCM	France	42	165	I
EXOCET (MM-40)	ASCM	France	70	165	I
NETHERLANDS					
RGM-84A (HARPOON)	ASCM	USA	120	220	I
NIGERIA					
EXOCET (MM-38)	ASCM	France	42	165	I
EXOCET (MM-40)	ASCM	France	70	165	I
OTOMAT (Mk 2)	ASCM	Italy	180	210	I
NORWAY					
PENGUIN (Mk 3)	ASCM	Domestic	300	985	I
OMAN					
EXOCET (AM-39)	ASCM	France	50	165	I
EXOCET (MM-40)	ASCM	France	70	165	I
SEA EAGLE	ASCM	Italy	110	230	I
PAKISTAN					
HATF 1	BSRBM	Domestic	100	500	I
HATF 2	SRBM	Domestic	300	500	I
HATF 3	SRBM	Domestic	600	500	D
M-11	SRBM	China	300	800	I
FL-1	ASCM	China	40	513	I
HY-2 (SILKWORM)	ASCM	China	95	513	I
EXOCET (MM-40)	ASCM	France	70	165	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
PERU					
EXOCET (AM-39)	ASCM	France	50	165	I
EXOCET (MM-40)	ASCM	France	70	165	I
OTOMAT (Mk 2)	ASCM	Italy	180	210	I

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
POLAND					
SS-21 (SCARAB)	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
AS-1 KENNEL (KS-1)	ASCM	Russia	100	1,000	I
AS-9 KYLE (Kh-28)	ASCM	Russia	90	200	I
PORTUGAL					
AGM-84A (HARPOON)	ASCM	USA	120	220	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
QATAR					
EXOCET (AM-39)	ASCM	France	50	165	I
EXOCET (MM-40)	ASCM	France	70	165	I
ROMANIA					
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
AS-1 KENNEL (KS-1)	ASCM	Russia	100	1,000	I
AS-9 KYLE (Kh-28)	ASCM	Russia	90	200	I
RUSSIA					
SS-1 SCUD B (R-17)	SRBM	Domestic	300	985	I
SS-11 SEGOR (S-10)	ICBM	Domestic	13,000	1-3RV	I
SS-13 SAVAGER (S-12)	ICBM	Domestic	9,400	1RV	I
SS-17 SPANKER (RS-16)	ICBM	Domestic	10,000	4 RV	I
SS-18 SATAN (RS-20)	ICBM	Domestic	11,000	10RV	I
SS-19 STILETTO (RS-18)	ICBM	Domestic	10,000	6 RV	I
SS-21 SCARAB (Tochka)	BSRBM	Domestic	120	480	I
SS-24 SCALPEL (RS-22)	ICBM	Domestic	10,000	10RV	I
SS-25 SICKLE (RS-12M)	ICBM	Domestic	10,500	1RV	I
SS-X-26	SRBM	Domestic	400	800	E
SS-X-27	ICBM	Domestic	10,000	1RV	E
SS-N-6 SERB (RSM-25)	SLBM	Domestic	3,000	650	I
SS-N-8 SAWFLY (RSM-40)					
SAUDI ARABIA					
CSS-2 (DF-3)	IRBM	China	2,800	2,150	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
OTOMAT (Mk 2)	ASCM	Italy	180	210	I
SEA EAGLE	ASCM	UK	110	230	I
SERBIA					
SA-2 (mod.)	BSRBM	Russia	80	130	I
K-15 (KRAIJINA)	SRBM	Domestic	150	nk	D
SCUD (mod.)	SRBM	Domestic	400	700	D
SS-N-2c STYX (P-21)	ASCM	Russia	85	513	I

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
SINGAPORE					
EXOCET (AM-39)	ASCM	France	50	165	I
GABRIEL II	ASCM	Israel	36	100	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
SOMALIA					
SS-N-2a STYX (P-15)	ASCM	Russia	43	513	I
SLOVAKIA					
SS-21 SCARAB (Tochka)	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
SOUTH AFRICA					
ARNISTON	MRBM	Domestic	1,500	1,000	T
EXOCET (AM-39)	ASCM	France	50	165	I
SKORPIOEN	ASCM	Domestic	36	100	I
SKORPIOEN II	ASCM	Domestic	nk	nk	D
SKUA	LACM	Domestic	800	100	D
SPAIN					
CAPRICORNIO	SLV	Domestic	1,300	500	D
RGM-84A (HARPOON)	ASCM	USA	120	220	I
SWEDEN					
KEPD 50 / 250	LACM	Germany	50/250	nk	D
RB 08A	ASCM	Domestic	250	250	I
RBS 15	ASCM	Domestic	90	250	I
SYRIA					
SS-21 SCARAB (Tochka)	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
SS-1 SCUD C	SRBM	North.Korea	550	500	I
M-9 (CSS-6/DF-15)	SRBM	China	600	950	O
AS-1 KENNEL (KS-1)	ASCM	Russia	100	1,000	I
SS-N-3b SEPAL (P-7)	ASCM	Russia	450	1,000	I
TAIWAN					
GREEN BEE (Ching Feng)	BSRBM	Domestic	130	400	I
SKY HORSE (Tien Ma)	MRBM	Domestic	950	500	D
HSUING-FENG 1	ASCM	Domestic	36	100	I
HSUING-FENG 2	AS/LACM	Domestic	170	75	I
HSUING-FENG 3	AS/LACM	Domestic	300	nk	D
THAILAND					
EXOCET (MM-38)	ASCM	France	42	165	I
FL-1	ASCM	China	40	513	I
GABRIEL II	ASCM	Israel	36	100	I
AGM-84A HARPOON	ASCM	USA	120	220	I
RGM-84A HARPOON	ASCM	USA	120	220	I
YJ-1 / C-801	ASCM	China	40	165	I

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
TUNISIA					
EXOCET (MM-40)	ASCM	France	70	165	I
TURKEY					
RGM-84A (HARPOON)	ASCM	USA	120	220	I
U.A.E.					
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
EXOCET (MM-40)	ASCM	France	70	165	I
U.K.					
TRIDENT (C5)	SLBM	USA	12,500	MIRV	I
ALARM	LACM	Domestic	45	nk	I
EXOCET (MM-38)	ASCM	France	42	165	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
SEA EAGLE	ASCM	Domestic	110	230	I
TOMAHAWK (TLAM-D)	LACM	USA	1,296	450	O
UKRAINE					
SS-21 SCARAB (Tochka)	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
SS-19 STILETTO (RS-18)	ICBM	Russia	10,000	6 MIRV	N
SS-24 SCALPEL (RS-22)	ICBM	Russia	10,000	10 MIRV	N
AS-4 KITCHEN (Kh-22)	LA/ASCM	Russia	400	1,000	I
AS-6 KINGFISH (KSR-5)	LA/ASCM	Russia	400	1,000	I
AS-15 KENT (Kh-55)	LACM	Russia	3,000	200kt N	I
SS-N-2c STYX (P-21)	ASCM	Russia	85	513	I
U.S.A.					
ATACMS (MGM-140)	BSRBM	Domestic	135	450	I
MINUTEMAN 3 (LGM-30G)	ICBM	Domestic	14,800	3 MIRV	I
PEACEKEEPER (LGM-118)	ICBM	Domestic	11,000	10 MIRV	I
TRIDENT C4 (UBM-93A)	SLBM	Domestic	7,400	5 MIRV	I
TRIDENT C5 (UGM-133A)	SLBM	Domestic	12,500	5 MIRV	I
AGM-69 (SRAM)	LACM	Domestic	200	170 kt N	I
AGM-84A (HARPOON)	ASCM	Domestic	120	220	I
RGM-84A (HARPOON)	ASCM	Domestic	120	220	I
RGM-84D (HARPOON)	ASCM	Domestic	277	220	I
UGM-84A (HARPOON)	ASCM	Domestic	120	220	I
AGM-84E (SLAM)	LACM	Domestic	100	220	I
AGM-86B (ALCM)	LACM	Domestic	2,500	200kt N	I
AGM-86C (CALCM)	LACM	Domestic	2,500	450	I
AGM-129 (ACM)	LACM	Domestic	3,000	450 N	I
AGM-131 (SRAM-2)	LACM	Domestic	400	250N	I
AGM-142 (HAVE NAP)	LACM	Domestic	100	395	I
TOMAHAWK (TLAM-N)	LACM	Domestic	2,500	N	I
TOMAHAWK (TASM)	ASCM	Domestic	480	480	I

Country/System (Alt. Name)	Type	Supplier	Range	Payload	Status
TOMAHAWK (TLAM-C)	LACM	Domestic	1,650	320	I
TOMAHAWK (TLAM-D)	LACM	Domestic	1,296	450	I
VENEZUELA					
OTOMAT (Mk 2)	ASCM	Italy	180	210	I
RGM-84A (HARPOON)	ASCM	USA	120	220	I
VIETNAM					
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
SS-N-2 b STYX (P-20)	ASCM	Russia	50	513	I
YEMEN					
SS-21 SCARAB (Tochka)	BSRBM	Russia	120	480	I
SS-1 SCUD B (R-17)	SRBM	Russia	300	985	I
SS-N-2b STYX (P-20)	ASCM	Russia	50	513	I

The Master Tables are a complete listing of the ballistic and cruise missile capabilities of all countries which currently possess such weapons in their armouries, exluding unguided artillery rockets such as the Russian Frog-7 and ballistic missiles with ranges of less than 50 km.

ABBREVIATIONS & RANGE CLASSIFICATION: BALLISTIC MISSILES

Battlefield Short-Range Ballistic Missile (BSRBM): up to 150 km/up to 94 miles
Short-Range Ballistic Missile (SRBM): 150 - 799 km/94 - 499 miles
Medium-Range Ballistic Missile (MRBM): 800 - 2,399 km/500 - 1499 miles
Intermediate-Range Ballistic Missile (IRBM): 2,400 - 5,499 km/1,500 - 3,437 miles
Intercontinental-Range Ballistic Missile (ICBM): 5,500 km plus/3,438 miles plus
Submarine-Launched Ballistic Missile (SLBM): No Specific Range
Classification:
KT: Kiloton (Nuclear Yield)
MIRV: Multiple Independently Targetable Re-Entry Vehicle (Nuclear)
RV: Re-Entry Vehicle (Nuclear)
Non-Op.: Non-Operational [Warheads Removed]
ABBREVIATIONS
ASCM: Anti-Ship Cruise Missile: No Specific Range Classification
LACM: Land-Attack Cruise Missile: No Specific Range Classification
HD: Harassment Drone: No Specific Range Classification
I: In Service
D: Development
N: Non-Operational
E: Tested
T: Terminated
O: On Order
C: Cancelled

Appendix D: Post WWII Conflicts Involving Ballistic and Cruise Missiles[101]

Date	Conflict	Missiles Used	Type	Fired by	Fired Against
1967	Arab-Israeli	SS-N-2 Styx	ASCM	Egypt	Israeli Destroyer Eilat
1971	Indo-Pakistan	SS-N-2 Styx	ASCM	India	Pakistani Ships
1973	Yom Kippur	Scud B	SRBM	Egypt	Israel
		FROG-7	BSRBM	Egypt, Syria	Israel
		AS-5 Kelt	LA/ASCM	Egypt	Israeli Ships
		Gabriel 1	ASCM	Israel	Egyptian Ships
1982	Falklands	AM-39 Exocet	ASCM	Argentina	British Ships
1980/88	Iran-Iraq	FROG-7	BSRBM	Iraq	Iran
		Scud B	SRBM	Iraq	Iran
		Al Hussein	SRBM	Iraq	Iran
		Armat	ASCM	Iraq	Iranian Ships
		AM-39 Exocet	ASCM	Iraq	Iran Ships, USS Stark
		HY-2 Silkworm	ASCM	Iraq	Iranian Ships
		FAW-70	BSRBM	Iraq	Iranian Ships
		Oghab	BSRBM	Iran	Iraq
		Iran-130	BSRBM	Iran	Iraq
		Scud B	SRBM	Iran	Iraq
		HY-2 Silkworm	ASCM	Iran	Iraqi Ships
1986	US-Libya	Scud B	SRBM	Libya	USNB Lampedusa, IT
		AGM-84A	ASCM	USA	Libyan Ships
1988-95	Afghanistan	Scud B	SRBM	Afghan Army	Mujaheddin
		Scud B	SRBM	Mujaheddin	Kabul
1991	Persian Gulf	FROG-7	BSRBM	Iraq	Saudi Arabia
		Al Hussein	SRBM	Iraq	Israel, S.A., Bahrain
		Al Hijarah	SRBM	Iraq	Israel
		HY-2 Silkworm	ASCM	Iraq	USS Wisconsin
		Tomahawk	LACM	USA	Iraq
		AGM-86C	LACM	USA	Iraq
		AGM-84E	LACM	USA	Iraq
		RGM 84A	ASCM	S. Arabia	Iraqi Ships
1993	Persian Gulf	Tomahawk	LACM	USA	Iraq
1994	Yemen	Scud B	SRBM	N. Yemen	San'a, South Yemen
1994	Iran-Iraq	Scud B	SRBM	Iran	Mujaheddin bases, IZ
1994-5	Yugoslavia	Mod. SA-2	(mod)	Bosnia Serbs	Bihac Pocket
1995	Yugoslavia	Tomahawk	LACM	USA	Bosnian Serbs

Appendix E: Movement Attributes of Generic Scud Brigade[102]

Attributes	Speed	Units
Secondary Road	30.0	km/h
Primary Road	40.0	km/h
Major Road	50.0	km/h
Spur Track Rail	0.0	km/h
Single Track Rail	0.0	km/h
Double Track Rail	0.0	km/h
Open Fields	15.0	km/h
Scattered Trees	10.0	km/h
Light Forests	5.0	km/h
Dense Forests	0.0	km/h
Villages	30.0	km/h
Towns	20.0	km/h
Cities	15.0	km/h
0-2% slope, % of base	1.0	km/h
3-5% slope, % of base	0.8	km/h
6-10% slope, % of base	0.4	km/h
11-20% slope, % of base	0.1	km/h
21-30% slope, % of base	0.0	km/h
30-40% slope, % of base	0.0	km/h
45+% slope, % of base	0.0	km/h
Small River Crossing delay	75.0	minutes
Medium River Crossing delay	110.0	minutes
Large River Crossing delay	150.0	minutes
Secondary Road Bridge Crossing delay	40.0	minutes
Primary Road Bridge Crossing delay	25.0	minutes
Major Road Bridge Crossing delay	15.0	minutes
Spur Track Rail Crossing delay	90.0	minutes
Single Track Rail Crossing delay	50.0	minutes
Double Track Rail Crossing delay	30.0	minutes
Sleet or Hail, % of base	0.8	km/h
Dust or Smoke, % of base	0.8	km/h
Fog or Haze, % of base	0.8	km/h
Light Rain, % of base	0.9	km/h
Moderate Rain, % of base	0.8	km/h
Heavy Rain, % of base	0.7	km/h
Light Snow, % of base	0.5	km/h
Moderate Snow, % of base	0.3	km/h
Heavy Snow, % of base	0.1	km/h
Frozen Ground, % of base	1.2	km/h

ENDNOTES

[1] Dick Cheney, *Conduct of the Persian Gulf Conflict: An Interim Report to Congress*, (Washington, D.C.: Department of Defense, July 1991), Introduction.

[2] Center for Defence and International Security Studies, *Master Missile Tables*, available from http: / / www.cdiss.org; Internet; accessed 30 December 1996.

[3] The threat comes not just from other nations. there are also implications for terrorist and other criminal organizations. Many have feared that some of the nuclear, chemical, or biological stockpiles of the former Soviet Union would end up in the hands of these supra-national organizations. Indeed, some have harbored trepidation for the arsenal of the U.S. and NBC capable nations. President William J. Clinton, in his *A National Security Strategy of Engagement and Enlargement*, (Washington, D.C.: The White House, 1996), 16, poses the issue for solution.

[4] Clinton, *A National Security Strategy of Engagement and Enlargement*, 20.

[5] Michael W. Ellis and Jeffrey Record argue persuasively, in their article, "Theater Ballistic Missile Defense and U.S. Contingency Operations," *Parameters*, vol. XXII, no. 1 (Spring 1992), 14, that the MCTR limits supply, but not the demand for ballistic and cruise missiles. Third-world countries understand the value added from possessing such weapons. Until something is done to quench their thirst for a cheap substitute for an air force, they will continue to attempt to acquire TMs.

[6] According to Mark Hewish and Barbara Starr, "Catching the Bullet: Theater Missile Defense Faces Reality," *International Defense* Review, vol. 27, no. 6 (June 1994): 31, James Woolsey, former U.S. Director of Central Intelligence has stated about third-world countries possessing TBMs, "some of these countries may place little stock in the classic theory of deterrence which kept the Cold War from becoming a hot one."

[7] The ability to locate and track Iraqi Scud missiles during DESERT STORM was one of the intelligence system's deficiencies during that conflict. This finding seems to be the current consensus, and is backed up by two Department of Defense reports: "Report of the Defense Science Board on Lessons Learned During Operations DESERT SHIELD & DESERT STORM," (Washington, D.C.: Office of the Director of Defense Research and Engineering, March 1993), 11, and Thomas P. Christie and William J. Barlow, "DESERT STORM Scud Campaign," (Alexandria, VA: Institute for Defense Analysis, April 1992), 2.

[8] U.S. Department of Defense, *Joint Pub 3-01.5: Doctrine for Joint Theater Missile Defense*, (Washington, D.C.: Joint Chiefs of Staff, 22 February 1996), viii.

[9] *Jane's Strategic Weapons Systems*, Issue 22, September 1996 gives the CEP for the Scud B as 450 meters. Variants can range wildly either way. Since most of the countries possessing TBMs have unmodified versions, this paper will use Jane's CEP for ease of discussion.

[10] There is evidence that the Iraqi's used commercially purchaed GPS receivers to accurately position their launchers. Without such a device, extensive surveying of possible launch sites would be necessary. If this was so, then the implications are tremendous. Information came from Tom Blau, "TMD in the Clinton Era," *Military Technology*, 7/93, (July 1993), 17.

[11] Artur Knoth, "GPS Technology and Third World Missiles," *International Defense Review*, vol. 25, no. 5 (May 1992): 413.

[12] Ibid., 414.

[13] Maurice Eisenstein, "Early Entry Forces: An Annotated Briefing on the Question of New and Nonconventional Threats," (Santa Monica, CA: RAND Corporation, 1995), xi.

[14] In the aftermath of DESERT STORM, the U.S. Department of Defense and Army have admitted to shortcomings in the Patriot air defense missile system. What initially was calculated as a greater than 90 percent kill ratio has now been downgraded to about 25 percent. This recalculation was a result of the independent U.S. Government Accounting Office report, "Operation Desert Storm: Data Does Not Exist to Conclusively Say How Well Patriot Performed," Report to Congressional Requesters (Washington, D.C.: 1992), 2-4.

[15] W. Seth Carus, *Cruise Missile Proliferation in the 1990s*, (Washington, D.C.: Praeger, 1992), 20.

[16] Kneale T. Marshall, "The Roles of Counterforce and Active Defense in Countering Theater Ballistic Missiles," (Monterey, CA: Naval Postgraduate School, September 1993), 16.

[17] Joseph P.Mattis, "The Application of Random Search Theory to the Detection of Tactical Ballistic Missile Launchers," (Monterey, CA: Naval Postgraduate School, September 1993), 9.

[18] Several authors, among them Bernard Brodie, James J. Wirtz, and Michael W. Ellis and Jeffrey Record, posit a first strike against missile systems. The missile systems are certainly easier to deal with while still in garrison, but the political implications are far too serious to conduct such an audacious action without unambiguous warning of an opponents intended use against U.S. and/or allied partners. The Israelis learned a bitter

lesson in their strike on the Al Mishab reactor complex in 1987. Although publicly chastised for their aggressive acts to end the Iraqi nuclear weapons program by conducting air attacks against two of their nuclear reactors, the west was at least relieved at the Iraqi set back.

[19] These lessons are condensed from two Department of Defense reports: "Report of the Defense Science Board on Lessons Learned During Operations DESERT SHIELD & DESERT STORM," and Christie and Barlow, "DESERT STORM Scud Campaign." See these reports for specific details into the lessons learned on the Scud hunt in DESERT STORM.

[20] Dr. Schneider, among others, has expounded on the concept of the "empty battlefield" in at two separate pieces: "The Theory of the Empty Battlefield," *Journal of the Royal United services Institute for Defence Studies*, (September 1987): 37-44, and "Vulcan's Anvil: The American Civil War and the Emergence of Operational Art," Fort Leavenworth, KS: School of Advanced Military Studies, 1 March 1988, 14. This phenomenon occurred because of four almost simultaneous inventions: the minie' ball for the rifled musket, a breech-loading system, the magazine, and smokeless powder. The impact of these four inventions, was an expansion of the width and depth of the battlefield through protective dispersion to compensate for the increasing lethality and ranges of weapons.

[21] The area covered by indirect fire systems is equal to $A = ((1/2)\ R_1\theta - (1/2)\ R_2\theta)$, where R_1 is the maximum range of the system, R_2 is the minimum range of the system, and θ is the lateral traverse angle multiplied by two. For the Scud B, the author used a maximum range of 300 kilometer, a minimum range of 45 kilometers, and a traverse angle of about 28°. Minimum range and traverse angles were derived using data in David C. Isby's, *Weapons and Tactics of the Soviet* Army, New York: Jane's publishing Inc, 1988), 294. Artillery information is based on a notional 30 kilometer maximum range, one kilometer minimum range, and 28° traverse angle.

[22] Using the formula for exhaustive search ($E(T) = (1/2)\ A/VW$) found on page 1-2 in Alan R. Washburn's, *Search and Detection*, Arlington: Operations Research Society of America, 1981, it is clear that the search becomes more problematic with increasing ranges of missiles. In the formula, A is the area to be searched, V is the velocity of the search vehicle, and W is the field of vision that the sensor can acquire. From this formula, it becomes apparent that the time (T) to complete an exhaustive search for a 300 kilometer range TM is roughly 237.5 hours. This, of course, is using an unrefueled single Pioneer UAV searcher with a field of view (FOV) of 800 meters, at an altitude of 2,500 meters, and with a 930 kilometer per hour velocity. Using the formula Of course the land area available for launch mitigates the exponential rise in area to be searched.

[23] Brian Nichiporuk and C. H. Builder, "Information Technologies and the Future of Land Warfare," (Santa Monica, CA: prepared for the United States Army by the Rand Corporation, 1995), 18.

[24] John L. Petersen, *The Road to 2015: Profiles of the Future*, (Corte Madera: Waite Group Press, 1994), 30.

[25] Kenneth P. Werrell, *The Evolution of the Cruise Missile*, (Maxwell Air Force Base, Alabama: Air University Press, 1985) 43-44.

[26] Carus, *Cruise Missile Proliferation in the 1990s*, 99.

[27] Werrell, *The Evolution of the Cruise Missile*, 47.

[28] Ibid, 44-50.

[29] Ibid, 50.

[30] Ibid., 62.

[31] Robert G. Nagler, *Ballistic Missile Proliferation: An Emerging Threat, 1992*, (Arlington, VA: System Planning Corporation, 1992) 5.

[32] George Lindsey, "Ballistic Missile Defence in the 1990s," *Canadian Defence Quarterly*, vol. 25, no. 1 (September 1995): 6.

[33] Ellis and Record, "Theater Ballistic Missile Defense and US Contingency Operations," 19.

[34] Jill L. Jermano and Susan E. Springer, "Monitoring Road-Mobile Missiles Under START: Lessons from the Gulf War," *Parameters*, vol. 23, no. 1 (Spring 1993): 71-76.

[35] Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report*, (Washington, D.C.: Government Printing Office, 1993) 43.

[36] The Scud missile is a short range tactical ballistic missile. It can reach out to about 300 kilometers. First fielded in the 1950s, the Scud can carry a warhead of between 2,000 and 4,000 kilograms. The Iraqi Al-Husayn, a derivative of the Scud-B can only carry a warhead of 190 kilograms, but achieves a range of 650 kilometers. Furthermore, Iraq had also employed the Al Abbas a 900 kilometer range missile, but with much reduced accuracy and warhead size.

[37] James Blackwell, *Thunder in the Desert*, (New York: Bantam Books, 1991), 137-139.

[38] Keaney and Cohen, *Gulf War Air Power Survey Summary Report*, 85-90.

[39] U.S. Department of Defense, "Report of the Defense Science Board on Lessons Learned During Operations DESERT SHIELD & DESERT STORM," 11.

[40] Ibid., 11.

[41] Keaney and Cohen, *Gulf War Air Power Survey Summary Report*, 65.

[42] U.S. Army, *Field Manual 34-130: Intelligence Preparation of the Battlefield*, (Washington, D.C.: Department of the Army, 8 July 1994), 1-1.

[43] U.S. Department of Defense, *Joint Pub 3-01.5: Doctrine for Joint Theater Missile Defense*, III-11.

[44] Mattis, "The Application of Random Search Theory to the Detection of Tactical Ballistic Missile Launchers." viii.

[45] Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton: Princeton University Press, 1976), 348.

[46] Thomas W. Hair, "The Application of Search Theory to the Timely Location of Tactical Ballistic Missiles," (Monterey: Naval Postgraduate School, March 1993), 10.

[47] Sun Tzu, *Art of War*, trans. Ralph D. Sawyer (Boulder: Westview Press, Inc. 1994), 140.

[48] According to *Janes Military Vehicles and Logistics*, ed. Christoper F. Foss and Terry J. Gorden, (Coulston, EN: Janes Information Group Limited, 1996), 331, the MAZ-543 TEL is a 12 meters long, eight wheel drive vehicle that weighs 29,000 kilograms fully loaded, and can attain speeds up to 63 kilometers per hour on hard surfaces. It has a range of 1,525 kilometers. Its engine is a powerful 525hp engine that, along with the eight wheel drive suspension, allows it to traverse a 57% gradient and rugged terrain.

[49] Yu. V. Chuyev and Yu. B. Mikhaylev, *Forecasting in Military Affairs: A Soviet View*, trans. Government of Canada (Washington, D.C.: U.S. Government Printing Office, 1975), 31.

[50] The IR sensors on DSP cannot see through clouds, fog, or heavy haze. The further along that a missile can travel before it is detected, the less protection the target

has to prepare for a strike, or defend against the missile. Furthermore, the more time the launcher has to get away before attack assets vector in on his location.

[51] Joseph S. Bermudez, Jr., "Iraqi Missile Operations During 'Desert Storm'," *Janes Soviet Intelligence Review*, vol. 3, no. 3 (March 1991): 134.

[52] Sun Tzu, *Art of War*, 135.

[53] Keaney and Cohen, *Gulf War Air Power Summary Report*, 85-86.

[54] Rick Atkinson, *Crusade: The Untold Story of the Persian Gulf War*, (New York: Houghton Mifflin Company, 1993), 176.

[55] The D3A was developed as a sequential process for working through targeting issues. It incorporates cross-battlefield operating systems techniques to achieve a directed, synergistic approach.

[56] Paul E. Girard, "A Function-Based Definition of (C2) Measures of Effectiveness," in *Science of Command and Control: Part II, Coping with Complexity*, Stuart E. Johnson and Alexander H. Levis, (Washington, D.C.: AFCEA International Press, 1989), 119.

[57] Ibid., 118.

[58] U.S. Department of Defense, *Joint Pub 3-01.5: Doctrine for Joint Theater Missile Defense*, II-7.

[59] Ibid., III-11.

[60] U.S. Department of Defense, *Joint Pub 3-01.5: Doctrine for Joint Theater Missile Defense*, III-12.

[61] Clausewitz, *On War*, 1976,

[62] Martin van Creveld in his book *Command in War*, (Cambridge: Harvard University Press, 1985) introduces three types of command and control. Command-by-direction is the oldest and least used in present times. It implies direct involvement by the commander in all facets of the decision making process. In essence, no decisions are made without his approval. The obvious disadvantage with command-by-direction it is dependent on one man making the right decision, at the right time, and in the right place. Initiative is stifled. The commander must choose the proper location, information, and time to make his decision. Command-by-plan is the second form of command and control. In it detailed plans are produced to direct the operations of the force. Command-by-plan fights friction as much as it does the enemy. It is expressly designed to operate with great

uncertainty. The deficiency is that little deviance from the plan is allowed. Command-by-influence is the final form of command and control. It is epitomized in the German form of a*uftragstaktik* (mission-type orders). Broad guidance and plan outlines is provided to subordinate units along with the minimum goals required for success. It places great reliance on the initiative of the individual soldiers and units along the chain of command to achieve the goals as best as they can based on the current situation.

[63] Thomas J. Czerwinski, "Command and Control at the Crossroads," *Parameters*, vol. XXVI, no. 2 (Summer 1996): 124.

[64] Alan Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War," *International Security*, vol. 17, no. 3 (Winter 92/93): 77.

[65] Frank Kendall asserts, in his article "Exploiting the Military Technical Revolution: A Concept for Joint Warfare," *Strategic Review*, Spring 1992: 25, that the ATO was nominally a three day process. This was true for the most part. JFACC could change it at the last moment due to current exigencies (See Keaney and Cohen, *Gulf War Air Power Summary Report*, 151). For requests other than USCENTCOM's, however they were rarely honored.

[66] Keaney and Cohen, *Gulf War Air Power Summary Report*, 86-87.

[67] Dennis McDowell, "Theater Missile Defense: A Joint Enterprise." *Joint Force Quarterly*, no. 3 (Winter 1993-94): 87.

[68] Roy M. Gulick and Anne W. Martin, "Managing Uncertainty in Intelligence Data -- An Intelligence Imperative." in *Science of Command and Control: Coping with Uncertainty*, Stuart E. Johnson and Alexander H. Levis, Washington, D.C.: AFCEA International Press, 10-11.

[69] Automatic target recognition (ATR) is the name given to the on-board artificial intelligence capability to identify and classify targets of interest to the airframe commander. There are two levels of ATR discrimination: detection and tracking, and recognition or identification. The latter is obviously the higher-level and thus more difficult to accomplish. Researchers have explored three branches: multi-sensor fusion, electro-optical, and radar. For each of these branches, technicians have tried four basic algorithms: match filter, statistical pattern recognition, model-based vision, and neural networks. Match filtering uses image-processing algorithms incorporating target templates. Statistical pattern recognition samples target images for specific details of the target signature. Model-based vision compares observations with pre-stored computer models. These are the most capable of dealing with high-clutter environments and different scenarios. Neural networks, which simulate brain activity, are believed to provide the most promising technology. True ATR capabilities are expected by the turn of the century. The information contained herein was gathered from two sources:

Christine Castro, "Automatic Target Recognition Shows promise," *Defense Electronics*, vol. 22, no. 8 (August '90): 49-52; Raman K. Mehra, et. al. "Automatic Target Recognition for Joint STARS Using Flexible Templating," (Woburn, MA: Scientific Systems Company, Inc., 12 May 1995), 1-6; and William H. Bennett, "Automatic Detection of Scud Tracks from MTI Radar Data: MTI Radar Motion Pattern Exploitation Technology Development," (Greenbelt, MD: Atlantic Aerospace Electronics Corp, 9 October 1996).

[70] The ability to geolocate TELs and associated missiles after launch for destruction has been modeled and practiced extensively. According to Barbara Starr, "Winning the 'Scud' Wars," *Jane's Defence Weekly*, vol. 21, no. 7 (19 February 1994): 40 the U.S. Air Force is experimenting with identification and attack times within a 10 minute window. This requires an extremely quick missile detection, within the range of 30 seconds, and an agile cueing architecture to get the attack aircraft on station within the time allotted from launch. John Boatman's article, "Army Plans Two Minute Warning." *Jane's Defense Weekly*, vol. 23, no. 24 (17 June 1995): 27-29, tells of the U.S. Army's efforts in Joint Precision Strike Demonstration (JPSD). The Roving Sands exercise is an annual test of these capabilities.

[71] U.S. Department of Defense, "Report of the Defense Science Board on Lessons Learned During Operations DESERT SHIELD & DESERT STORM," 11.

[72] Search theory was developed by the U.S. Navy as a theoretical construct upon which to base anti-submarine warfare (ASW) operations. The similarities bound up in the hunt for TMs are striking. Both offer similar challenges and uncertainties. First, submarines and TMs operate in large patchy areas with small numbers of targets for the volume of space. Second, both control stealthy mobile craft that hide most of the time and come out only when needed to fire or move. Third, both need to come out in the open to fire their munitions. On the other hand, three major disunities exist between the two systems and scenarios. Submarines need to operate relatively close to enemy ships to threaten them. This is not the case with TMs. TMs can operate well within the national boundaries and strike thousands of miles, depending on the missile. The sensor array used to detect submarines is different than those than can be deployed against TMs. ASW searches depend on acoustic detection. This option is not open to TM searches. Lastly, submarines act independently. They do not require sustainment and C2 the way TMs do. TM operations are more coordinated in their actions. Much of the above was gleaned from Mattis, "The Application of Random Search Theory to the Detection of Tactical Ballistic Missile Launchers," 12-14.

[73] Mattis, "The Application of Random Search Theory to the Detection of Tactical Ballistic Missile Launchers," viii.

[74] Coverage ratio is a measure of the search effort needed to attained the requisite detection probability. The greater the coverage ratio the greater the probability of detection when a TEL or resupply vehicle is exposed.

[75] Mattis, "The Application of Random Search Theory to the Detection of Tactical Ballistic Missile Launchers," 37-39.

[76] Girard, "A Function-Based Definition of (C2) Measures of Effectiveness," 118-119.

[77] Gabriel Frenkel, "Flexible Architectures for Sensor Fusion in Theater Missile Defense," (Alexandria, VA: Institute for Defense Analysis, April 1994), 21.

[78] Ibid., 17-18.

[79] David Foxwell, "An Alternative Approach to Distinguishing Cruise Missiles," *International Defense Review*, vol. 24, no. 4 (April 1991); James R. Wolf, "Implication of Space-Based Observation," *Military Review*, vol. 74, no. 4 (April 1994); Hal Gershanoff, "Using EO/IR to Find Threats," *Electronic Defense*, vol. 16, no. 2 (February 1993), and Alan D. Campen, "New Technology Alters Support to Intelligence," *Signal*, vol. 47, no. 2 (October 1992) provides excellent indications of the direction sensor technology is proceeding in the next ten to twenty years. "Leveraging the Infosphere: Surveillance and Reconnaissance in 2020," *Airpower Journal*, vol. 9, no. 2 (Summer 1995) speculates on future possibilities.

[80] Jeffrey T. Rickelson, "Volume of Data Cripples Tactical Intelligence System," *Armed Forces Journal International*, vol. 129, no. 11 (June 92): 37.

[81] Frenkel, "Flexible Architectures for Sensor Fusion in Theater Missile Defense," 16.

[82] Steven R. Mann, "Chaos Theory and Strategic Thought," *Parameters*, vol. XXII, no. 3 (Autumn 1992), 67.

[83] U.S. Department of Defense, *Joint Pub 1-02: DoD Dictionary of Military and Associated Terms*, (Washington, D.C.: Joint Chiefs of Staff, March 1994), 36.

[84] Ibid., 36.

[85] U.S. Department of Defense, *Joint Pub 3-01.5: Doctrine for Joint Theater Missile Defense*, viii.

[86] U.S. Department of Defense, *Joint Pub 1-02: DoD Dictionary of Military and Associated Terms*, 69-70.

[87] U.S. Department of Defense, *Joint Pub 3-12: Doctrine for Joint Nuclear Operations*, (Washington, D.C.: Joint Chiefs of Staff, December 1995), II-5.

[88] Knoth, "GPS Technology and Third World Missiles," 413.

[89] Ibid., 413.

[90] U.S. Army, *Field Manual 34-2: Collection Management and Synchronization Planning*, Washington, D.C.: Department of the Army, 8 March 1994, Glossary-6.

[91] Ibid., Glossary-6

[92] U.S. Army, *Field Manual 34-130: Intelligence Preparation of the Battlefield*, 1-1.

[93] U.S. Department of Defense, *Joint Pub 1-02: DoD Dictionary of Military and Associated Terms*, 220.

[94] U.S. Department of Defense, *Joint Pub 1-02: DoD Dictionary of Military and Associated Terms*, 227.

[95] Ibid., 228.

[96] U.S. Army, *Field Manual 34-2: Collection Management and Synchronization Planning*, Glossary-6.

[97] Ibid., Glossary-7.

[98] U.S. Department of Defense. *Joint Pub 3-01.5: Doctrine for Joint Theater Missile Defense*, I-2.

[99] Center for Defence and International Security Studies, *Master Missile Tables*, available from http: / / www.cdiss.org; Internet; accessed 30 December 1996.

[100] Ibid.

[101] Ibid.

[102] Demetrios Sapounas, and Thomas Kreitzberg, "The Tactical Movement Analyzer," (Dahlgren, VA: Naval Surface Warfare Center, September 1994), 5.

BIBLIOGRAPHY

BOOKS

Atkinson, Rick. *Crusade: The Untold Story of the Persian Gulf War*. New York: Houghton Mifflin Company, 1993.

Bertalanffy, Ludwig von. *General Systems Theory*. New York: George Braziller, 1968.

Blackwell, James. *Thunder in the Desert: The Strategy and Tactics of the Persian Gulf War*. New York: Bantam Books, 1991.

Brams, Steven J. *Superpower Games: Applying Game Theory to Superpower Conflict*. New Haven: Yale University Press, 1983

Carius, W. Seth. *Ballistic Missiles in the Third World: Threat and Response*. Washington, D.C.: Praeger, 1990.

_____. *Cruise Missile Proliferation in the 1990s*. Washington, D.C.: Praeger, 1992.

Chuyev, Y.V. and Mikhaylev, Y.B. *Forecasting in Military Affairs: A Soviet View*. Moscow, 1975.

Clausewitz, Carl von. *On War*. ed. and trans. Michael Howard and Peter Paret, Princeton: Princeton University Press, 1976.

Creveld, Martin van. *Command in War*, Cambridge: Harvard University Press, 1985.

French, Simon. *Decision Theory: An Introduction to the Mathematics of Rationality*. Chichester: Ellis Horwood Limited, 1986.

Isby, David C. *Weapons and Tactics of the Soviet Army*. New York: Jane's Publishing Inc, 1988.

Foss, Christoper F. and Gorden, Terry J. ed. *Janes Military Vehicles and Logistics*, Coulston, EN: Janes Information Group Limited, 1996.

Lennox, Duncan, ed. *Jane's Strategic Weapons Systems*, Issue 22, Coulston, EN: Janes Information Group Limited, September 1996.

Johnson, Stuart E., et al., ed. *Dominant Battlespace Knowledge*. Washington: National Defense University, 1996.

_____. *Science of Command and Control: Coping with Uncertainty*. Washington: National Defense University, 1988.

_____. *Science of Command and Control: Part II Coping with Complexity*. Washington: National Defense University, 1989.

Keaney Thomas A. and Cohen, Eliot A. *Gulf War Air Power Survey Summary Report*. Washington, D.C.: Government Printing Office, 1993.

Lewin, Roger. *Complexity*. New York: MacMillan, 1992.

McKnight, Clarence E. ed. *Control of Joint Forces: A New Perspective*. Fairfax: AFCEA International Press, 1989.

Robert G. Nagler. *Ballistic Missile Proliferation: An Emerging Threat, 1992*. Arlington, VA: System Planning Corporation, 1992.

Navias, Martin S. *Going Ballistic: The Build-up of Missiles in the Middle East*. London: Brassey's (UK), 1993.

Payne, Keith B. *Missile Defense in the 21st Century: Protection Against Limited Threats*. Boulder: Westview Press, 1991.

Petersen, John L. *The Road to 2015: Profiles of the Future*, Corte Madera: Waite Group Press, 1994.

Shubik, Martin. *The Use and Method of Gaming*. New York: Elsevier Scientific Publishing Company, Inc., 1975.

Senge, Peter M. *The Fifth Dimension: The Art and Practice of the Learning Organization*. New York: Currency Doubleday, 1990.

Simpkins, Richard E. *Race to the Swift: Thought on Twenty-First Century Warfare*. London: Brassey's Defence Publishers, 1985.

Tzu, Sun. *Art of War*, trans. Ralph D. Sawyer, Boulder: Westview Press, Inc. 1994.

Waldrop, M. Mitchell. *Complexity: The Emerging Science at the Edge of Chaos*. New York: Simon and Schuster, 1992.

Washburn, Alan R. *Search and Detection*. Arlington: Operations Research Society of America, 1981.

Werrell, Kenneth P. *The Evolution of the Cruise Missile*, Maxwell Air Force Base, Alabama: Air University Press, 1985.

Woodward, Bob. *The Commanders*. New York; Pocket Books, 1991.

ARTICLES

Beyerchen, Alan. "Clausewitz, Nonlinearity, and the Unpredictability of War." *International Security*, vol. 17, no. 3 (Winter 92/93): 59-90.

Bermudez, Joseph S. Jr. "Iraqi Missile Operations During 'Desert Storm'." *Jane's Soviet Intelligence Review*, vol. 3, no. 3 (March 1991): 131-135.

______. "Iraqi Missile Operations During 'Desert Storm' - Update." *Jane's Soviet Intelligence Review*, vol. 3, no. 5 (May 1991): 225.

Blau, Tom. "TMD in the Clinton Era," *Military Technology*, 7/93 (July 1993), 16-22.

Boatman, John. "Army Plans Two Minute Warning." *Jane's Defense Weekly*, vol. 23, no. 24 (17 June 1995): 27-29.

Castro, Christine. "Automatic Target Recognition Shows promise," *Defense Electronics*, vol. 22, no. 8 (August '90): 49-52.

Czerwinski, Thomas J. "Command and Control at the Crossroads." *Parameters*, vol. XXVI, no. 2 (Summer 1996): 121-132.

Ditto, William L. and L.M. Pecora. "Mastering Chaos." *Scientific American* (August 1993): 78-84.

Durham, George A. "Developing TTP for Theater Missile Defense." *Field Artillery* (September - October 1995): 17-21.

Ellis, Michael W. and Record, Jeffrey. "Theater Ballistic Missile Defense and U.S. Contingency Operations." *Parameters*, vol. XXII, no. 1 (Spring 1992): 11-26.

Fox, Eugene; and Orman, Stanley. "TMD: A Phoenix from Star Wars' Ashes." *Jane's Defense Weekly*, vol. 22, no. 13 (1 October 1994): 30-33.

Foxwell, David. "An Alternative Approach to Distinguishing Cruise Missiles." *International Defense Review*, vol. 24, no. 4 (April 1991): 344.

Gershanoff, Hal. "Using EO/IR to Find Threats." *Journal of Electronic Defense*. vol. 16, no. 2 (February 1993): 39-43.

Hewish, Mark. "Aerial Reconnaissance: Imagery Exploitation Adds Value." *International Defense Review*, vol. 26, no. 10 (October 1993): 828-832.

_____. "Airborne Ground Surveillance: New Technologies Meet Urgent Demands." *International Defense Review*, vol. 28, no. 1 (January 1995): 34-39.

Hewish, Mark and Starr, Barbara. "Catching the Bullet: Theater Missile Defense Faces Reality," *International Defense* Review, vol. 27, no. 6 (June 1994): 31-32.

Herskowitz, Don. "On the Road from Data to Intelligence." *Journal of Electronic Defense*. vol. 16, no. 10 (October 1993): 95-102.

Jermano, Jill L., and Springer, Susan G. "Monitoring Road-Mobile Missiles Under START: Lessons from the Gulf War." *Parameters*. vol. 23, no. 1 (Spring 1993): 70-80.

Kendall, Frank. "Exploiting the Military Technical Revolution: A Concept for Joint Warfare." *Strategic Review*, Spring 1992: 23-30.

Knoth, Artur. "GPS Technology and Third World Missiles." *International Defense Review*, vol. 25, no. 5 (May 1992): 413-415.

Lennox, Duncan. "Cruise: A Missile for the '90s." *Jane's Defense Weekly*, vol. 21, no. 18 (7 May 1994): 19-20.

Lindsey, George. "Ballistic Missile Defense in the 1990s." *Canadian Defense Quarterly*, vol. 25, no. 1 (September 1995): 6-11.

Lloyd, Seth. "The Calculus of Intricacy." *The Sciences* (October 1990): 38-44.

Mann, Steven R. "Chaos Theory and Strategic Thought." *Parameters*, vol. XXII, no. 3 (Autumn 1992): 54-67.

McDowell, Dennis. "Theater Missile Defense: A Joint Enterprise." *Joint Force Quarterly*, no. 3 (Winter 1993-94): 80-87.

Peters, Ralph. "Winning Against Warriors." *Strategic Review* (Summer 1996): 12-21.

Richelson, Jeffrey T. "Volume of Data Cripples Tactical Intelligence System." *Armed Forces Journal International* (June 92): 35-37.

Schneider, James J. "Black Lights: Chaos, Complexity and the Promise of Information Warfare," *Net Call* (January 1996).

_____. "The Theory of the Empty Battlefield," *Journal of the Royal United Services Institute* (September 1987): 37-42.

Starr, Barbara. "Winning the 'Scud' Wars." *Jane's Defense Weekly*, vol. 21, no. 7 (19 February 1994): 40.

Wolf, James R. "Implication of Space-Based Observation," *Military Review*, vol. 74, no. 4 (April 1994): 75-85.

GOVERNMENT PUBLICATIONS

The White House. *A National Security Strategy of Engagement and Enlargement.* Washington, D.C.: The White House, 1996.

U.S. Army. *Battle Command: Leadership and Decision Making for War and Operations Other Than War.* FT Leavenworth, KS: Battle Command Battle Laboratory, 22 April 1994.

U.S. Army. *Field Manual 6-20-10: Tactics, Techniques, and Procedures for The Targeting Process.* Washington, D.C.: Department of the Army, 8 May 1996.

U.S. Army. *Field Manual 34-1: Intelligence and Electronic Warfare Operations.* Washington, D.C.: Department of the Army, 27 September 1994.

U.S. Army. *Field Manual 34-2: Collection Management and Synchronization Planning.* Washington, D.C.: Department of the Army, 8 March 1994.

U.S. Army. *Field Manual 34-2-1: Reconnaissance and Surveillance and Intelligence Support to Counterreconnaissance.* Washington, D.C.: Department of the Army, 19 June 1991.

U.S. Army. *Field Manual 34-3: Intelligence Analysis.* Washington, D.C.: Department of the Army, 15 March 1990.

U.S. Army. *Field Manual 34-130: Intelligence Preparation of the Battlefield.* Washington, D.C.: Department of the Army, 8 July 1994.

U.S. Army. *Learning Lessons in a Force Projection Army.* CALL Newsletter 93-2. FT. Leavenworth, KS. Center for Army Lessons Learned. May 1993.

U.S. Department of Defense. *Conduct of the Persian Gulf Conflict: An interim Report to Congress.* Washington, D.C.: Office of the Secretary of Defense, July 1991.

U.S. Department of Defense. *Joint Pub 1-02: DoD Dictionary of Military and Associated Terms.* Washington, D.C.: Joint Chiefs of Staff, March 1994.

U.S. Department of Defense. *Joint Pub 2-0: Joint Doctrine for Intelligence Support to Operations.* Washington, D.C.: Joint Chiefs of Staff, 5 May 1995.

U.S. Department of Defense. *Joint Pub 3-0: Doctrine for Joint Operations*. Washington, D.C.: Joint Chiefs of Staff, 1 February 1995.

U.S. Department of Defense. *Joint Pub 3-01.5: Doctrine for Joint Theater Missile Defense*. Washington, D.C.: Joint Chiefs of Staff, 22 February 1996

U.S. Department of Defense. *Joint Pub 3-55: Doctrine for Reconnaissance, Surveillance, and Target Acquisition Support for Joint Operations (RSTA)*. Washington, D.C.: Joint Chiefs of Staff, 14 April 1993.

U.S. Department of Defense. *Joint Pub 3-55.1 Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles*. Washington, D.C.: Joint Chiefs of Staff, 27 August 1993.

U.S. Department of Defense. *Joint Pub 6-0: Doctrine for Command, Control, Communications, and Computer (C4) Systems Support to Joint Operations*. Washington, D.C.: Joint Chiefs of Staff, 30 May 1995

U.S. Department of Defense. *Proliferation: Threat and Response*. Washington, D.C.: Office of the Secretary of Defense, April 1996.

U.S. Department of Defense. "Report of the Defense Science Board on Lessons Learned During Operations DESERT SHIELD & DESERT STORM," Washington, D.C.: Office of the Director of Defense Research and Engineering, March 1993.

U.S. Government Accounting Office. "Operation Desert Storm: Data Does Not Exist to Conclusively Say How Well Patriot Performed." Report to Congressional Requesters Washington, D.C.: 1992.

BRIEFINGS

Eisenstein, Maurice. "Early Entry Forces: An Annotated Briefing on the Question of New and Nonconventional Threats." Santa Monica, CA: RAND Corporation, 1995.

STUDIES

Bennett, William H. "Automatic Detection of Scud Tracks from MTI Radar Data: MTI Radar Motion Pattern Exploitation Technology Development." Greenbelt, MD: Atlantic Aerospace Electronics Corp, 9 October 1996.

Berhow, T. et al. "A Theater Ballistic Missile (TBM) Counterforce Concept." Monterey, CA: Naval Postgraduate School, December 1993.

Bondanella, J.R. et.al. "Estimating the Army's Intelligence Requirements and Capabilities for 1997-2001: Analytic Support to the Intelligence Relook Task Force." Santa Monica, CA: RAND, 1993.

Cothron, Tony L. "Achieving the Revolutionary Potential of Information Technology." Newport, RI: Naval War College, March 1996.

Christie, Thomas P. and Barlow, William J. "DESERT STORM Scud Campaign." Alexandria, VA: Institute for Defense Analysis, April 1992.

Drell, S. et al. "Verification Technology: Unclassified Version." McLean, VA: The MITRE Corporation, October 1990.

Faint, D. R. "Joint Special Operations Intelligence Support A Critical Analysis." Carlisle Barracks, PA: Army War College, 20 March 1993.

Ficken, Earl I. "Tactical Missile Defense: A Chink in the Armor?" Newport, RI: Naval War College, 19 June 1992.

Frenkel, Gabriel. "Flexible Architectures for Sensor Fusion in Theater Missile Defense." Alexandria, VA: Institute for Defense Analysis, April 1994.

Glenn, James. "Chaos Theory: The Essentials for Military Applications." Newport, RI: Naval War College, 21 February 1995.

Hair, Thomas W. "The Application of Search Theory to the Timely Location of Tactical Ballistic Missiles." Monterey, CA: Naval Postgraduate School, March 1993.

Junker, Vernon L. "Tactical Unmanned Aerial Vehicles in a Proposed Joint Infrastructure to Counter Theater Ballistic Missiles." Monterey, CA: Naval Postgraduate School, March 1995.

Kammann, Richard W. Jr. "Computer Model and Simulation of a Theater Ballistic Missile (TBM) Counterforce Plan Involving a Lethal Unmanned Air Vehicle (UAV)." Monterey, CA: Naval Postgraduate School, September 1995.

Litchfield, Bruce A. "Theater Ballistic Missile Defense: The Need for an Operational Commander." Newport, RI: Naval War College, 16 June 1995.

Mansager, Bard k. "JANUS Modeling for the Environmental Effects for Distributed Interactive Simulation (E2DIS) Program." Monterey, CA: Naval Postgraduate School, April 1995.

Marshall, Kneale T. "The Roles of Counterforce and Active Defense in Countering Theater Ballistic Missiles." Monterey, CA: Naval Postgraduate School, September 1993.

Mattis, Joseph P. "The Application of Random Search Theory to the Detection of Tactical Ballistic Missile Launchers." Monterey, CA: Naval Postgraduate School, September 1993.

Mehra, Raman K.; Ravichandran, B.; Bhattacharija, A.; and Greenspan, M. "Automatic Target Recognition for Joint STARS Using Flexible Templating." Woburn, MA: Scientific Systems Company, Inc., 12 May 1995.

Nagler, Robert G. "Ballistic Missile Proliferation: An Emerging Threat 1992." Arlington, VA: Systems Planning Group, October 1992.

Nichiporuk, Brian and C. H. Builder. "Information Technologies and the Future of Land Warfare." Santa Monica, CA: prepared for the United States Army by the Rand Corporation, 1995.

Sapounas, Demetrios and Kreitzberg, Thomas. "The Tactical Movement Analyzer." Dahlgren, VA: Naval Surface Warfare Center, September 1994.

Schlientz, Steven C. "Improving Theater Ballistic Missile Defense at the Operational Level." Newport, RI: Naval War College, 20 May 1996.

Schneider, James J. "The Theory of Operational Art." Fort Leavenworth, KS: School of Advanced Military Studies, 1 March 1988.

______. "Vulcan's Anvil: The American Civil War and the Emergence of Operational Art." Fort Leavenworth, KS: School of Advanced Military Studies, 1 March 1988.

Sternberg, Joseph, Thackery, Ross, and Johnson, Frederick. "A New Methodology for Assessing the Military Value of Tactical Intelligence and Surveillance Systems." Monterey, CA: Naval Postgraduate School, May 1995.

Wirtz, James J. "Counterforce and Theater Missile Defense: Can the Army Use and ASW Approach to the Scud Hunt." Carlisle Barracks, PA: Army War College, 25 March 1995.

Zappalia, Steve. "Joint Theater Missile Defense: An Army Assessment." Fort Leavenworth, KS: Command and General Staff College, 4 June 1993.